The officer in charge suggests the advisability of procuring more suitable and economical appliances for prosecuting this work. He estimates that a suitable outfit can be procured for about $15,000, and that the running expense for the coming fiscal year would be about $15,000, more, making the total that could be profitably expended, $30,000.

July 1, 1882, amount available	$859 25
Amount appropriated by act passed August 2, 1882	10,000 00
	10,859 25
July 1, 1883, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1882	5,980 65
July 1, 1883, amount available	4,878 60
Amount that can be profitably expended in fiscal year ending June 30, 1885.	30,000 00

(See Appendix S 10.)

11. *Saline River, Arkansas.*—The object of this work is to clear the river of snags and overhanging trees. The operations are carried on by hired labor furnished with the necessary outfit. The work of the season commenced at Longview and extended down to Godfrey's Landing, a distance of about 50 miles.

The total distance that has been worked over on this stream, from Big Island, the place of beginning, to Godfrey's Landing, is 230 miles, leaving 20 miles yet remaining to its junction with the Ouachita.

July 1, 1882, amount available	$2,474 32
Amount appropriated by act passed August 2, 1882	4,000 00
	6,474 32
July 1, 1883, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1882	4,128 25
July 1, 1883, amount available	2,346 07
Amount (estimated) required for completion of existing project	17,651 00
Amount that can be profitably expended in fiscal year ending June 30, 1885.	10,000 00

(See Appendix S 11.)

12. *Current River, Missouri and Arkansas.*—With the small balance of $534.83 which remained available for this work at the end of the last fiscal year a boat and crew were hired for a few days during last September to work upon this stream. During the time they were so employed eighty-five snags were removed between the mouth and Shoemaker's Landing. Total amount of appropriations to date, $7,000. Congress having omitted this item from the river and harbor act of 1882, it is assumed that a further prosecution of this work is not at present desired. No estimate is therefore submitted.

(See Appendix S 12.)

IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS—IMPROVING HARBOR AND MISSISSIPPI RIVER AT ALTON—MISSISSIPPI RIVER OPPOSITE THE CITY OF SAINT LOUIS, AND AT OR NEAR CAPE GIRARDEAU AND MINTON POINT—IMPROVEMENT OF OSAGE RIVER IN KANSAS AND MISSOURI.

Officer in charge, Maj. O. H. Ernst, Corps of Engineers, having under his immediate orders First Lieut. F. V. Abbot, Corps of Engineers.

1. *Mississippi River between the Illinois and Ohio rivers.*—Work was carried on at Arsenal Island, Horsetail, Twin Hollows (west bank), Twin Hollows (east bank), Pulltight, Beard's Island, "Jim Smith's," Chesley

Island, Foster's Island, Piasa Island, and Alton Harbor. All of these works except the last two constitute part of one connected whole, carried on under the general scheme of making the improvement continuous, beginning at Saint Louis and working down-stream, reducing the river to an approximately uniform width of about 2,500 feet, and protecting its banks from erosion.

Arsenal Island.—The project for the improvement of this locality was adopted in 1876, its object being to stop the erosion of the west side of Arsenal Island and the consequent deterioration of the navigation. The amount expended during the year was $6,535.92. The total amount expended to June 30, 1883, is $30,732.65, and has resulted in the protection of 7,843 feet of bank, a part of which, measuring 2,923 feet in length, is not quite completed, though nearly so. It is proposed to complete the unfinished portions.

Horsetail.—The present project for the improvement of this locality was adopted in 1873, and modified in 1879, the object being to afford a channel not less than 8 feet deep.

The natural channel was often not more than 4 feet in depth and was tortuous. The amount expended during the year was $51,473.93. The total amount expended to June 30, 1883, is $361,556.60, of which, however, but $355,863.20 has been employed upon the system adopted in 1879. It has resulted in securing a direct navigable channel, with a depth not less than 8½ feet.

Further work will be required to preserve these results, the amount of which is a matter of future contingency.

Twin Hollows, west bank.—The present project for the improvement of this locality was adopted in 1881, the object being to afford a channel not less than 8 feet deep. The natural channel was often not more than 4 feet deep in the shoalest parts. The amount expended during the year was $93,136.91. The total amount expended to June 30, 1883, is $196,037.16, and has resulted in securing a navigable channel in which the depth during the year has not been less than 8 feet, but which is still tortuous, though less so than last year. It is intended during the coming year to thoroughly repair the works already constructed, and to push them forward as rapidly as it shall be found practicable to straighten the channel without interfering with navigation.

Twin Hollows, east bank.—The present project for the improvement of this locality was adopted in 1881, the object being to stop the caving, which extended over a length of 8,400 feet of the bank, and the consequent deterioration of the navigation. Before the work was begun the caving was progressing at the rate of several feet per day. The amount expended during the year was $23,232.31. The total amount expended to June 30, 1883, is $95,928.94, and has resulted in the protection of 8,025 feet of bank, of which 2,800 feet is completed, and the remainder well advanced. It is proposed during the coming year to complete the unfinished portions.

Pulltight.—The present project for the improvement of this locality was adopted in 1881, the object being to afford a channel not less than 8 feet deep. The natural channel was often not more than 4 feet deep in the shoalest parts. The amount expended during the year, which includes all expenditures to June 30, 1883, was $46,465.47, and has resulted, in connection with the works at Twin Hollows, west bank, in securing a navigable channel in which the depth during the year was not less than 8 feet. Much further work will be required before this result can be considered permanent. It is proposed during the coming year to extend the works down-stream to connect with Beard's Island.

Beard's Island.—The present project for the improvement of this locality was adopted in 1881, the object being to close a small chute north of the island, and to stop the erosion of the west side of the island and the consequent deterioration of the navigation. Before the work was begun the caving was progressing at the rate of several feet per day and the water in the chute was 40 feet deep. The amount expended during the year was $55,810.47. The total amount expended to June 30, 1883, is $84,258.76, and has resulted in closing the chute and stopping the caving throughout the length of the island, a distance of 7,300 feet, of which 2,500 feet is completed and the remainder well advanced.

"Jim Smith's."—The present project for the improvement of this locality was adopted in 1881, the object being to afford a channel not less than 8 feet deep. The natural channel was often not more than 4 feet deep in the shoalest parts.

The amount expended during the year was $103,418.37. The total amount expended to June 30, 1883, is $114,486.74, and has resulted in securing a navigable channel in which the depth during the year was not less than 8½ feet. External causes contributed to this depth, which is not regarded as permanent without much further work. It is proposed during the coming year to thoroughly repair the works already constructed, and to extend them down-stream as rapidly as the limited means available will permit.

Chesley Island.—The present project for the improvement of this locality was adopted in 1881, the object being to stop the erosion of the east side of the island, and the consequent deterioration of the navigation, and also to close the chute west of the island, in order to afford, in connection with the works at "Jim Smith's," a channel not less than 8 feet deep. The bank was caving at the rate of several feet per day, and the natural channel was often not more than 4 feet deep in the shoalest parts. The amount expended during the year, which includes all expenditures to June 30, 1883, was $47,401.39, and has resulted in the protection of the east side of the island for a length of 4,305 feet, and in partially closing the chute, affording, in connection with the works at "Jim Smith's" and external causes, a navigable channel in which the depth during the year was not less than 8½ feet. Much further work will be required to make this depth of channel permanent. It is proposed during the coming year to complete the closure of the chute and to build out the Missouri Bank below the island.

Foster's Island.—The present project for the improvement of this locality was adopted in 1881, its object being to stop the caving of the west side of the island and the consequent deterioration of the navigation. Before the work was begun the caving was progressing at the rate of several feet per day. The amount expended during the year, which includes all expenditures to June 30, 1883, was $5,779.18, and has resulted in the partial protection of 580 feet of the bank. It is proposed during the coming year to continue the protection to the foot of the island, a distance of about 4,000 feet.

Piasa Island.—There is not at this time any definite project for the improvement of this locality. A dam constructed in 1875–1877 having become a dangerous obstruction to navigation, immediate relief to the latter was given by removing a portion of the dam. The amount expended was $2,750.11.

Alton Harbor.—The present project for the improvement of this harbor was adopted in 1881, the object being to remove a shoal in front of the down-stream portion of the landing. The amount expended during the year was $34,000. The total amount expended to June 30, 1883, is

$67,324.70, and has resulted in removing a large part of the shoal. The works are still acting favorably upon the shoal, and it is not proposed to do anything more here until their final results shall be developed.

Estimate.—The officer in charge modifies and increases his total estimate for the final completion of the improvement.

The appropriation of $1,000,000 asked for is to be applied to completing the works now progressing and to beginning new works below Foster's Island. From the changeable nature of the stream it is not practicable to give in advance the names of the exact localities where work will be required. The programme is to make the improvement continuous, working down-stream from Saint Louis, by reclaiming land and building up new banks, thus reducing the width of the river to the uniform width of about 2,500 feet. Caving banks are to be protected. The appropriation of the above sum is recommended.

July 1, 1882, amount available		$112,145 18
Miscellaneous receipts		86 04
Amount appropriated by act passed August 2, 1882		600,000 00
		712,231 82
July 1, 1883, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1882	$510,995 09	
July 1, 1883, outstanding liabilities	5,991 15	
		516,986 24
July 1, 1883, amount available		195,245 58
Amount (estimated) required for completion of existing project		14,152,500 00
Amount that can be profitably expended in fiscal year ending June 30, 1885		1,000,000 00

(See Appendix T 1.)

2. *Harbor and Mississippi River at Alton.*—The present project for the improvement of this harbor was adopted in 1881, the object being to remove a shoal in front of the down-stream portion of the landing. The amount expended during the year was $34,000, allotted by Congress from the general appropriation for improving the Mississippi River from Cairo to the Illinois River. The total amount expended to June 30, 1883, is $67,324.70, and has resulted in removing a large part of the shoal. As the works are still acting favorably it is not proposed to do anything more here until their final results shall be developed.

The appropriation of $5,000 asked for is to be used for completing the dike as originally designed should that become necessary and filling up any depressions that may occur from settlings. Such work, if it be required at all, cannot well be postponed.

Amount (estimated) required for completion of existing project	$5,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1885	5,000 00

(See Appendix T 2.)

3. *Mississippi River opposite the city of Saint Louis, Missouri.*—The present project for the improvement of this locality was adopted in 1882, the object being to increase the available length of river front opposite Saint Louis by reclaiming the land occupied by Cahokia Chute, also to stop the erosion at high water of the Illinois shore in Cahokia Chute, and, furthermore, to perpetuate the good results previously obtained under a different project in the channel depth. Before the work was begun a considerable body of water passed through Cahokia Chute at the higher stages, and a small body at low stage, preventing access to the navigable water west of Arsenal Island; a slight erosion of the Illinois shore occured at the higher stages, destroying

land of considerable value; and a portion of the west side of Arsenal Island was in need of protection in order to perpetuate the good channel already existing there. The amount expended during the year, which includes all expenditures to June 30, 1883, was *$47,067.95, and has resulted in partially protecting the west side of Arsenal Island, and in shutting off the water from Cahokia Chute at a stage about 7 feet higher than before. It is proposed during the coming year to complete the protection of the west side of Arsenal Island, and the hurdles employed in silting up the chute.

July 1, 1882, amount available		$60,000 00
July 1, 1883, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1882	$32,900 54	
July 1, 1883, outstanding liabilities	1,003 40	
		33,903 94
July 1, 1883, amount available		26,096 06
Amount (estimated) required for completion of existing project		26,096 06

(See Appendix T 3.)

4. *Mississippi River at or near Cape Girardeau, Missouri, and Minton Point, Illinois.*—The present project for the improvement of this locality was adopted in 1881, the object being to remove a large and growing bar in front of the Cape Girardeau Landing and to provide an 8-foot channel between that place and Minton Point. The bar was dry at a stage 16 feet above low water, and the channel depth was liable to be as little as 4 feet. The amount expended during the year was $21,836.59. The total amount expended to June 30, 1883, is $65,366.55, of which $35,366.55 was added to the special appropriation from the funds provided for improving the Mississippi River between the Illinois and Ohio rivers, and has resulted in wholly removing the bar, and securing a channel to Minton Point, in which the depth during the year has not been less than 8 feet. Further work will be required to perpetuate these results, for which an appropriation is recommended.

Amount (estimated) required for completion of existing project	$41,820 04
Amount that can be profitably expended in fiscal year ending June 30, 1885.	42,000 00

(See Appendix T 4.)

5. *Osage River, Kansas and Missouri.—Below Tuscumbia.*—The present system of improvement employed below Tuscumbia was begun in 1871, the object being to afford a channel of navigable width not less than 2 feet deep.

The natural channel was frequently not more than 6 inches deep at many of the shoals. The amount expended during the year was $1,556.45. The total amount expended to June 30, 1883, is $169,427.02, and has resulted in increasing the depth to at least 2 feet over twenty-one shoals, and removing all snags and overhanging trees.

Above Tuscumbia.—The project for the improvement of the Osage above Tuscumbia was adopted in 1881, the object being to remove all snags and overhanging trees which obstructed navigation. In the natural state of the river many hundreds of these obstructions existed. The amount expended during the year was $8,316.98. The total amount expended to June 30, 1883, is $19,076.34, and has resulted in clearing the natural channel to Osceola, the head of navigation, 230½ miles from

*These figures are obtained by adding to the cash expenditures the cost of the service of equipment.

APPENDIX T.

IMPROVEMENT OF MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS—IMPROVING HARBOR AND MISSISSIPPI RIVER AT ALTON—MISSISSIPPI RIVER OPPOSITE THE CITY OF SAINT LOUIS, AND AT OR NEAR CAPE GIRARDEAU AND MINTON POINT—IMPROVEMENT OF OSAGE RIVER IN KANSAS AND MISSOURI.

REPORT OF MAJOR O. H. ERNST, CORPS OF ENGINEERS, OFFICER IN CHARGE, FOR THE FISCAL YEAR ENDING JUNE 30, 1883, WITH OTHER DOCUMENTS RELATING TO THE WORKS.

IMPROVEMENTS.

1. Mississippi River, between the Illinois and Ohio rivers.
2. Harbor and Mississippi River at Alton.
3. Mississippi River opposite the city of Saint Louis, Missouri.
4. Mississippi River at or near Cape Girardeau, Missouri, and Minton Point, Illinois.
5. Osage River, Kansas and Missouri.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., August 13, 1883.

GENERAL: I have the honor to transmit herewith the annual reports for the fiscal year ending June 30, 1883, upon the works under my charge.

Very respectfully, your obedient servant,

O. H. ERNST,
Major of Engineers.

Brig. Gen. H. G. WRIGHT,
Chief of Engineers, U. S. A.

T 1.

IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE ILLINOIS AND OHIO RIVERS.

Work has been carried on during the year at Arsenal Island, Horsetail, Twin Hollows, west bank, Twin Hollows, east bank, Pulltight, Beard's Island, "Jim Smith's," Chesley Island, Foster's Island, Piasa Island, and Alton Harbor.

Of these all except the last two form part of the general scheme for improving the navigation, making the improvement continuous, working down stream from Saint Louis. Their location is shown upon the Plate I which accompanied my last report.

The work at Alton was carried on in obedience to a special provision of the river and harbor act of August 2, 1882, and that at Piasa Island was rendered necessary by circumstances described further on.

ORGANIZATION.

First Lieut. F. V. Abbot, Corps of Engineers, was engaged upon special duties during the year until June 13, when he took charge of the work at Foster's Island.

The works at Piasa Island and Alton were under the immediate direction of Mr. C. D. Lamb, assistant engineer, who reported directly to me.

The organization for the other works was similar to that described in my last annual report; that is, there was at each work a resident engineer with one or more assistants, all being under the general supervision of a superintending engineer, through whom their reports to me were rendered.

There was an exception to this rule in the case of Foster's Island, after the assignment of Lieutenant Abbot to that work, his reports not passing through the superintending engineer. At the end of the year the other assignments were as follows, the prescribed duties of the different grades being the same as those described in my last report:

Superintending engineer: Mr. D. M. Currie.

Resident engineers: At Arsenal Island, Mr. C. D. Lamb; at Horsetail, Mr. E. D. Libby, assisted by Mr. S. B. Cady and Mr. C. P. Mitchell; at Twin Hollows, west bank, Mr. W. S. Mitchell, assisted by Mr. J. L. Duffy; at Twin Hollows, east bank, Pulltight, and "Jim Smith's," Mr. John O. Holman, assisted by Mr. A. F. Freis and Mr. B. E. Johnson; at Beard's Island, Mr. J. E. Savage; at Chesley Island, Mr. C. V. Mersereau, assisted by Mr. J. W. Irwin.

At the supply depot Mr. S. S. Van Norman had charge of the subsistence department, and Mr. C. L. Stevenson of the engineering supplies and repairs.

On board the steamer General Gillmore Mr. J. L. Stubblefield acted as general receiver of materials and measured the brush and stone.

The reports of the assistant engineers and of the supply clerk and subsistence clerk are herewith transmitted, constituting Appendixes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and are intended to form part of this report.

ARSENAL ISLAND PROTECTION.

A history of this work to the beginning of the fiscal year was given in my last annual report. Its location is shown upon Plate I. Operations were resumed in August, 1882, and consisted in completing the low-water protection to the foot of the island, and placing the medium stage protection, consisting of a layer of riprap, as material could be procured. Two mattresses 40 feet wide—one 460 feet long and the other 560 feet long—were placed below low-water mark. Riprap was deposited upon the bank above low-water mark over a total length of 3,253 feet. Of this 330 linear feet was carried to a height 16 feet above standard low water; 880 feet to a height 11½ feet above the same plane, and 2,043 feet to a height 8 feet. To complete the work it remains to extend the medium stage revetment over this length of 2,923 feet to the uniform height 16 feet above standard low water. For further details see Appendixes 1 and 2.

The total length of the protection is now 7,843 feet, of which 4,920 feet is completed, and the balance nearly so. The expenditures for the year were $6,535.92.

HORSETAIL.

Operations at this locality during the year consisted in repairing the works constructed in previous years, which have been fully described

in former reports, and in constructing a new hurdle to connect Carroll's Island with the Illinois shore. (See Plate II.) The latter work was rendered necessary by a strong draught of water towards the chute east of Carroll's Island, hindering the bank building process at the down-stream portion of the Horsetail Reach, and causing an enlargement of the chute referred to. Whatever may have been the cause of this tendency, it was much increased by a remarkable series of violent winds which blew almost continuously from the west for three months during the spring. The hurdle is 2,450 feet long and, though not quite completed, has had the desired effect of causing heavy deposits in its vicinity.

The process of building up the new banks has continued in a satisfactory manner, the results obtained from the recent flood being very large upon the Missouri side, and upon the Illinois side for a distance of 2 miles from the up-stream end, a height of several feet having been added to deposits previously secured.

In the down-stream portion on the Illinois side, the results for the entire year have been small, owing to circumstances above given, but they have been very large in the last few weeks, and are, as a whole, encouraging. Plate II shows the outlines of the bars as they appeared at a stage 11 feet above standard low water at the beginning and at the end of the year. The area upon which willows are growing has been much enlarged. For further details, see Appendixes 1 and 3.

The good result of the works upon the channel previously secured has been maintained, the least depth found during the low-water season of last autumn being 8½ feet, and the channel being direct and wide.

The expenditures during the year were $51,473.93.

TWIN HOLLOWS, WEST BANK.

Operations at this locality, the plan of which was described in my last report, were continued throughout the year, except when temporarily suspended during the winter or by the flood in June. The primary hurdle was extended down stream to a point about 11,600 feet from its up-stream end, being an addition of 2,800 feet to the length reported last year. Of this distance a portion 500 feet long being occupied by a high bar, was covered by a plantation of willows, instead of by a hurdle. The soil proved to be unfavorable and the willows died. To protect the deposits already secured at the up-stream end of the work, mattresses 104 feet wide were placed below low-water mark, and covered the space between the upper extremity of the primary line and a point 1,025 feet from it. The four secondary hurdles begun last year were repaired and extended towards the shore, and a fifth one was begun and nearly completed. The location of the works as they existed at the end of the year is shown upon Plate III. (For details, see Appendixes 1 and 4.)

Large deposits have been secured within the area to be reclaimed. Although much remains to be done in this direction, the channel has been prevented from splitting up, and the result has been of benefit to navigation.

The least depth found during the year was 8 feet. The channel crossing at the lower end of the works was pushed down-stream about 1,600 feet, which is a marked gain in the effort to straighten it.

The expenditures were $93,136.91.

TWIN HOLLOWS, EAST BANK.

In the work of protecting the Illinois bank at Twin Hollows, the slope below low-water mark had at the beginning of the year been covered

with mattresses 120 feet wide for a distance of 5,925 feet, and riprap had been deposited upon the bank above low water for a distance of 2,350 feet. A mattress in process of construction and not sunk had reached a length of 964 feet. The work was continued until October, when, having advanced as far as it was then advisable to carry it, it was suspended. The mattress, of which 964 linear feet had been constructed, was extended to a total length of 1,500 feet, and then placed in position. An additional mattress 1,210 feet long was fabricated and placed, and completed the low-water protection. As the bank above low water became graded to a gentle slope by the action of the river after the placing of the low-water mattress, riprap was deposited upon it, over the entire length of the mattress work. The height to which the riprap, or "medium stage protection," was carried, was not in all cases as great as will eventually be required, it being governed by the height to which the gentle slope extended. The total length of bank protected is 8,625 feet, of which about 2,800 feet has the riprap placed to a height 16 feet above standard low water, 2,300 feet to a height 14 feet, 1,325 feet to a height 12 feet, and 2,200 feet to a height 10 feet above the same plane. (See Plate IV.) (For further details, see Appendixes 1 and 5.)

The work has advanced beyond the limits of the caving bank, and has been completely successful in arresting the caving.

The expenditures during the year were $42,613.15.

PULLTIGHT.

The construction of a hurdle to connect the Illinois shore near Pulltight with the head of Beard's Island constituted a part of my project of January 28, 1881, for the improvement of the river between Carroll's Island and the mouth of the Meramec, the object being to connect Beard's Island and the tow-head above it with the main shore—see Plate III—thus building out the Illinois bank to the line indicated, and in connection with the works at Twin Hollows, west bank, reducing the width of the river.

A primary hurdle 2,860 feet long was constructed, and secondary hurdles Nos. 1 and 3 were begun. No. 3 was completed to its intersection with the towhead as the latter existed last autumn. The extraordinary series of westerly gales already referred to caused a rapid erosion of the towhead during the spring, and has increased the amount of work that will be required here. No. 1 had made but little progress when it was temporarily suspended by high water in June. Deposits have been secured to a satisfactory degree by the works constructed. They have aided in obtaining the beneficial results to navigation at Twin Hollows, before referred to. (For details, see Appendixes 1 and 6.)

The expenditures were $46,465.47.

BEARD'S ISLAND.

The revetment of the west side of Beard's Island was continued. At the beginning of the year the slope below low-water mark had been covered with mattresses 120 feet wide for a distance of 3,550 feet, beginning at the head of the island, and riprap had been deposited upon the bank above low water for a distance of 1,650 feet. A mattress in process of construction had reached a length of 550 feet, but no portion of it had been sunk. Early in July an attempt was made to place this mattress in position, but it failed and the mattress was lost. This dis-

aster was followed by others. (See Appendix 7.) The difficulties to be contended with were exceptionally great, but believing them to be not insuperable I was unable to acquit the resident engineer of a responsibility for the repeated failures, and accordingly in October relieved him from further duty at the work, placing his assistant in charge. From that time forward the progress was continuous, though slow. During the season the protection below low-water mark was extended downstream 3,850 feet, making its total length 7,300 feet, which covered the entire length of the island and a portion of the chute below, the latter having been filled up by deposits caused by the works near Pulltight. Riprap was deposited upon the bank above low water for a length of 3,500 feet. Of this, 850 feet was carried to a height 16 feet above standard low water, thus completing it; the remainder was carried to a height of about 6 feet above that plane. To complete the work it will be necessary to place the medium stage protection over a distance of 2,150 feet where no riprap has been placed, and to extend it up the face of the bank over a distance of 2,650 feet, where it has been partially placed. It is uncertain whether it will be necessary to plant willows for the high-water protection or not. All undermining and caving of the bank has been completely stopped. (For further details, see Plate V and Appendixes 1 and 7.)

The expenditures were $55,810.47.

CHESLEY ISLAND.

The revetment of the east side of Chesley Island and the closure of the chute on its west side constituted parts of my project of September 12, 1881, for the improvement of the river between the mouth of the Meramec and Illinois Station.

The case presented for the bank protection on the east side was that of a crossing, where the channel strikes the bank at an obtuse angle, necessitating a wide and deep protection.

The width of the mattress to be placed below low-water mark was fixed at 120 feet as in all similar cases. A single mattress 4,305 feet long was fabricated and placed in position covering so much of the island as required protection on that side. (See Plate VI.) This mattress, measuring 120 feet by 4,305 feet, or 516,600 square feet, is the largest yet constructed under my direction. It might have been made longer had any additional length been required. Riprap was deposited upon the bank above low water for a distance of 3,900 feet, of which 3,475 feet was carried to a height 16 feet above standard low water, the remaining 425 feet being carried only to a height 6 feet above that plane. To complete this part of the work it remains to place the medium stage protection for a distance of 564 feet where no riprap has been placed, and to extend it up the face of the bank for a length of 425 feet.

A revetment was placed also at the head of the island, extending in towards the chute. In this case a less width of mattress was considered sufficient. A mattress 40 feet wide and 550 feet long was placed below low-water mark, and riprap deposited upon the bank throughout this length.

A hurdle about 900 feet long to close the chute west of the island was begun and nearly completed. (See Plate III.)

The bank protection has been as successful here as it has elsewhere, all undermining and caving having been completely stopped. The hurdle has not as yet had time to accomplish any important result. For further details see Appendixes 1 and 8.

The expenditures were $47,401.39.

"JIM SMITH'S."

Operations at this locality were continued during the summer and autumn of 1882, in accordance with the plan described in my last annual report. (See Plate III.) At the beginning of the year the only work which had been done was the partial construction of the primary hurdle, which reached a length of about 1,000 feet. During the season this hurdle was extended down stream to a point 8,650 feet from the original point of beginning. Of this distance about 3,300 feet was occupied by a sand bar which was planted with cottonwood and willows. Six secondary hurdles were begun, of which numbers 1 and 5 were completed, and the others well advanced, the total length of secondary hurdles constructed being 7,600 feet.

The hurdles were much injured by ice in the break-up this spring. About 68 per cent. were reported to be in good condition afterwards. Contingencies of this kind bring the final cost of work done during the low-water season of the autumn well up towards that of work done in the spring, when the high water increases the difficulties of construction, but at the same time gives more prompt results in the shape of deposits.

Owing to the fact that no additional appropriations were made at the last session of Congress, work was not continued here in the latter half of the fiscal year, the available force being required elsewhere. It will be resumed as soon as this force can be spared from other work, which it is expected will be in August, 1883.

Considerable deposits have been secured within the area to be reclaimed, and the effect upon the channel has been beneficial. The least depth found during the year was 8½ feet, though this was partially to be attributed to the damming effect of a bad shoal at Sulphur Springs, just below. For details see Appendixes 1 and 9.

The expenditures were $103,418.37.

FOSTER'S ISLAND.

The revetment of the west side of Foster's Island constituted part of my project of September 12, 1881, for the improvement of the river between the mouth of the Meramec and Illinois Station, approved by your letter of November 2, 1881. During the summer of 1882 the bank caved with great rapidity, the shore line receding, in some cases, several hundred feet from the position occupied in 1881. The case presented was one requiring a wide and deep protection. The demands of other works rendered it impossible to begin this work until late in the season. One mattress 580 feet long was fabricated and sunk. The reduction of the force necessitated by the failure of additional appropriations rendered it impracticable to continue the work in the spring. It is expected that it can be resumed in a short time. So far as it extended, it had the desired result of arresting the undermining of the bank. For details see Appendix 10.

The expenditures were $5,779.18.

PIASA ISLAND.

In my project of August 26, 1880—see Annual Report of Chief of Engineers for 1881, page 1566—it was explained that it would be neces-

sary to remove a portion of the dam built across the chute south of Piasa Island by my predecessor in 1875–'77. Before that project could be carried into effect the funds available for its execution were by the river and harbor act of March 3, 1881, diverted to the improvement of Alton Harbor. Accordingly nothing was done at Piasa Island. The difficulty of navigating the north chute continued to increase until finally the high water of 1882 moved a large bar down over the mouth, shutting it off altogether during the succeeding low water. Steamboats were compelled to find their way through the south chute, seeking such depressions as existed in the dam for a passage over it. This became more and more dangerous as the stage of the river declined. A suspension of navigation at this point was threatened. Under these circumstances it was thought proper to depart from the programme previously laid down for the expenditure of the appropriation, and to allot to Piasa Island funds sufficient to make a safe passage-way through the dam.

It was found upon examination that the most suitable place for the opening was at the south end of the dam near the Missouri shore. An attempt was made to undermine the dam with the hydraulic excavator belonging to the works, arranged as in a Roy Stone dredge, but owing to the great depth—20 feet—of the foundation, it was not successful. The contrivance showed its efficiency as an excavator, however, raising in some cases 1,000 cubic feet of sand per hour. An arrangement was then made with Messrs. H. S. Brown & Co., of Quincy, Ill., to remove the dam, using the ordinary dredge. A cut was made, having a width of 385 feet and a least depth of 6 feet at low water, after which there was no obstacle to navigation at this place. For details see Appendix 11.

The expenditures were $2,750.11.

ALTON HARBOR.

The improvement of Alton Harbor was begun in September, 1881, under a separate appropriation for the "Improvement of the harbor and Mississippi River at Alton." My annual report of last year under that title—see Annual Report of Chief of Engineers for 1882, page 1644—gives a description of the plan adopted and the history of the operations up to that time. A dike opposite and above the town, running obliquely down-stream, had been begun, and was about one-third completed.

The river and harbor act of August 2, 1882, made provision for the improvement of the Mississippi River in the following language, viz:

* * * * * * *

Six hundred thousand dollars from Cairo to the Illinois River, including Alton Harbor, on which a sum not exceeding thirty-five thousand dollars shall be expended.

* * * * * * *

Work was accordingly begun in September, 1882, under this appropriation. It consisted of extending and raising the dike begun under the special appropriation.

The dike was extended to the full length contemplated, 4,800 feet. For a distance of 3,000 feet it was raised to its full height, 14 feet above low water; for a distance of 700 feet its height is 12 feet, and for the remaining 1,100 feet its height is but 10 feet above the same plane. To complete it as originally designed, it should be raised to the uniform height of 14 feet throughout, but it is not now certain that this will be necessary. It has exerted a very favorable influence upon the landing

at Alton, and as this action is still continuing, it is quite possible that the desired result will be attained without further work.

The work upon this dike has been carried on during three distinct periods, viz, the autumn of 1881, the spring of 1882, and the autumn of 1882. The amount accomplished during the first period was small, owing to unexpected floods, which occurred during what is usually the low-water season. About 3,500 cubic yards of dike were constructed, at a cost of $2.90 per cubic yard. During the second period the river was at about the average spring stage; the amount of work accomplished was about 20,200 cubic yards of dike, at a cost of $1.10 per cubic yard. During the third period the season was favorable, and the river was at a low stage; the amount accomplished was about 35,000 cubic yards, at a cost of 97 cents per cubic yard. Here is an excellent illustration of the contingencies to be met with in carrying on work upon the Mississippi River. Work which, under favorable circumstances, cost 97 cents per cubic yard, cost, under other circumstances, $2.90, or three times as much. The character of the work during the two periods was the same, and the season of the year was the same. The only difference in the circumstances came from the operations of nature, which could not be foreseen. It is plain that all estimates of cost made in advance can be no more than approximations.

For details of the work, see Appendix 12.

The expenditures were $34,000.

SUPPLY DEPOT.

For the better protection of the public property from petty depredators a board fence was constructed upon the northern and western sides of the yard, at a cost of $160 34. All of the smaller material used upon the works, such as rope, iron, wire, spikes, &c., and all subsistence stores were stored at the depot and issued as required. Many miscellaneous constructions and repairs were made, for details of which see Appendixes 1 and 13.

EQUIPMENT.

The hull of the steamer Anita having become unserviceable, her machinery was transferred to a new hull built for the purpose by Messrs. Howard & Co., at Jeffersonville, Indiana. The new boat has been named the General Gillmore. She is 140 feet long and 28 feet wide, and has been provided with every convenience for doing the work required of her. Her total cost, including three new steel boilers and outfit, thorough repair of the old machinery, and renewal of certain parts of it, was $20,171 24. The other principal additions to the equipment during the year were the construction of twenty-two portable buildings for quarters, &c., and nineteen small flats and the purchase of three second-hand coal barges.

A special record is kept in which the equipment is treated as so much unexpended appropriation. Each work is charged for the use and repair of such as may be employed upon it. The amounts given in this report as expended at each locality include the wear and tear of equipment.

The present valuation of the property remaining to be distributed in the future is given in the last column of the following table, in which are given also its valuation at the beginning of the year, the sums which

have been expended upon it, and its estimated deterioration during the year.

Class of property.	Balance July 1, 1882.	Debits.	Credits.	Balance June 30, 1883.
Steamer A. A. Humphreys	$21,199 16	$3,439 17	$3,846 77	$20,791 56
Steamer Anita	2,910 22	.....	2,910 22	.....
Steamer General Gillmore	.....	22,081 46	221 21	21,860 25
Launch Hornet	106 56	230 44	230 44	106 56
Launch Florence	.....	1,625 64	725 64	900 00
Tug Mignon	4,077 72	.....	.....	4,077 72
Barges	82,507 37	7,873 08	28,273 08	62,107 37
Pile-drivers	55,420 83	4,238 85	9,842 53	49,817 15
Quarter-boats, quarters, shops, &c	41,699 46	9,491 51	6,485 30	44,705 67
Skiffs, flats, &c	13,030 57	4,791 94	5,785 93	12,036 58
Tools and appliances	7,241 00	19,689 97	11,482 78	15,448 19
Hydraulic excavator	7,458 33	361 26	614 72	7,204 87
Ways for mattresses	5,711 09	468 34	847 74	5,331 69
Office furniture	913 36	522 35	258 50	1,177 21
Surveying instruments	1,751 80	44 65	364 85	1,431 66
Boarding outfit	12,358 95	4,092 73	1,386 61	15,065 07
Total	256,386 48	78,951 99	73,276 92	262,061 55

TELEPHONE LINE.

The telephone line constructed last year to the mouth of the Meramec was extended to Bushberg for the purpose of communicating with the work at Foster's Island. The price agreed upon with the Bell Telephone Company of Missouri for this extension was $1,932 for the first year and $655.20 for each succeeding year.

SUBSISTENCE.

The methods adopted for providing the force with subsistence are described in Appendix 14. The average cost of subsistence for each man per day during the spring of 1883 was 44 cents, including all expenses connected with the purchase, issue, and preparation of the supplies.

PILE-DRIVING.

As the driving of piles constitutes the largest single item of expense in the works of construction, it is important that the machines used for that work and the organization of the men engaged in it should be as perfect as possible. First Lieut. F. V. Abbot, Corps of Engineers, was assigned by my order of June 10, 1882, to a special study of the art of pile-driving in sandy soils, and made an elaborate series of observations, from which some interesting and valuable conclusions may be drawn. He ascertained that of $38,689.95 expended for labor in driving 20,000 piles, $14,255.94 was consumed in placing the driver in position. The conclusion is that a driver which will require least moving will, other things being equal, be most economical; or, in other words, that a driver furnished with several sets of leads promises good economical results. After careful observation of the steam hammer in use upon pile-drivers working at Chicago, Lieutenant Abbot concluded that there was little or no advantage in that form of hammer. He ascertained that the rapidity of penetration of piles sunk by the water-jet and hammer combined is remarkably uniform when the average of a great number of piles is considered, and when the depth does not exceed 16 feet, the rate being about the same for the last 2 feet as for the first two. His report is given in full as Appendix 15.

GAUGES.

The gauges at Grafton and Gray's Point were read daily. Their records are appended marked 16 and 17, respectively. The gauge at Alton was discontinued, it having been observed sufficiently long to give with accuracy the slope of the river between the mouths of the Illinois and Missouri, and there being no other necessity for a gauge so near to that at Grafton.

NAVIGABLE DEPTH BETWEEN SAINT LOUIS AND CAIRO.

The reports made to the association of Saint Louis and New Orleans pilots by its members have been transferred to me as in former years, and from them has been made a record of the depths found upon the bars between Saint Louis and Cairo throughout the year. So much of it as covers the low-water season is herewith transmitted, marked 18. As explained in former reports, strict accuracy is not claimed for any one measurement. The record, to be of value, should be taken as a whole; several day's measurements, and the gauge records, being considered together. The low-water season extended from a little after the middle of August until navigation was suspended by ice in December. The lowest stage reached was 1.9 feet above standard low water. The least depth reported and not contradicted was 5 feet and was found at Sulphur Springs, Forest Home, Kinney Point, and Jacket Pattern. A depth of 5½ feet was found at Cornice Island, Perry T. H., Liberty Island, and Crawford's. In all cases the least depth was found in October when the river was at a stage more than 3 feet above standard low water. The least depth found throughout the 21½ miles of river between Saint Louis and Kimmswick over which the works of improvement have extended was 8 feet.

MISSISSIPPI RIVER COMMISSION.

The river and harbor act of August 2, 1882, required that the sums appropriated by that act for improving the Mississippi River below the Des Moines Rapids should "be expended by the Secretary of War in accordance with the plans, specifications, estimates, and recommendations of the Mississippi River Commission created by the act approved June 28, 1879, or according to such plans, specifications, and estimates of the Engineer Department of the Army, which, having been approved by the Secretary of War, may be adopted by the said Mississippi River Commission for such parts of the said river as the said commission may not have completed the survey of." In compliance with your instructions of August 28, 1882, I submitted my plans and a copy of my project for the expenditure of the $600,000 appropriated for the Mississippi from Cairo to the Illinois River, by the act referred to, to the commission with a letter dated September 6, 1882. At their session of September 13–18, 1882, the commission approved and adopted the project, and a copy of their resolution to that effect was furnished me with your letter of September 26, 1882. In the mean time the works were progressing, and they have since continued without change in their administration.

ESTIMATE.

The estimate for the entire completion of the improvement which has been given in the annual reports from this office was made in 1875. The methods of construction upon which it was based proved inefficient

and were abandoned in 1879. There being no sufficient data for making an accurate estimate under the new methods of construction, the original estimate has, up to this time, been retained. The available data are not even now sufficient for an estimate which shall be entirely reliable, but it has become evident that the original estimate is too small. To avoid misleading Congress it is necessary to state this fact, and to make a new estimate which shall be as nearly accurate as present information will allow.

The contingencies of work upon the Mississippi are so great that any estimate based upon the number of linear feet of hurdle or other construction to be built, and the cost per linear foot, may be very erroneous. The original cost per linear foot may vary between wide limits, depending upon the weather and the stage of the river. By taking an average of several seasons an approximation to this cost may be reached, but the number of times that the silting devices may have to be repaired, or even entirely rebuilt, at any particular spot is uncertain. Evidently the only way to reach an accurate estimate is to take the cost per mile of some portion of the river which has been the subject of improvement for a number of years, where the circumstances are in general the same as those to be met with hereafter, and where the works have been entirely completed. There is at this time no portion of the river which fulfills all of these conditions. The present system of construction was first introduced at Horsetail in 1879. All other works of the same general character are of more recent date, the oldest of them, those at Twin Hollows, having been begun in the autumn of 1881. The works at Horsetail are further advanced towards completion than any others, and, though defective as a basis for estimating future cost, are the best for that purpose that exist.

The total amount that has been expended upon the improvement of the 5 miles of river known as Horsetail, under the present system and not including the cost of the original stone jetties, is $367,901.95. This includes $12,038.69 expended upon the protection of the west side of Carroll's Island. During the first two years of this work the forms of construction were largely experimental, they were undergoing modification, and their cost was larger than it would be again under the same circumstances of weather and river. To accomplish the same result $350,000 would now perhaps be sufficient. The desired effect upon navigation has been attained, a wide, deep, and direct channel having been procured, but it remains to secure these results by further building up of the new banks and consolidating and protecting the new land. The cost of this is the uncertain element in the present problem. I estimate it at not less than $25,000 per year for three years, or $75,000 in all, to be added to the $350,000 already expended. This gives a total of $425,000 for improving 5 miles of river, or $85,000 per mile. The forms of construction upon which it is based are applicable to the part of the Mississippi below the Missouri.

Between the Missouri and the Illinois other forms are used, and all circumstances of foundation, velocity of current, &c., are different. For this part of the river $37,500 per mile would, I think, be a reasonable estimate.

The distance from the mouth of the Missouri to the mouth of the Ohio is 205 miles. Of this distance 18 miles, from Gingrass Creek to the foot of Carroll's Island, has been improved; 14 miles from Carroll's Island to Bushberg, and 5 miles from Minton Point to Cape Girardeau will reach a stage of improvement with funds now available, which may, for present purposes, be considered half done, and about 16 miles in all

will not need improvement. These aggregate 43½ miles, leaving 161½ miles to be improved, which, at $85,000, will cost $13,327,500.

The distance from the mouth of the Illinois to the mouth of the Missouri is 24½ miles. The improvement of Alton Harbor has improved the general navigation for about 2½ miles, leaving 22 miles to be improved. This, at $37,500, will cost $825,000.

The total amount required for improving the Mississippi from the Illinois to the Ohio is therefore estimated at $14,152,500.

The amount which can be profitably expended during the year ending June 30, 1885, is $1,000,000. It is proposed to expend it in carrying out the programme heretofore adopted. This is to first improve the part of the river below Saint Louis, to make the improvement continuous, beginning at Saint Louis and working down stream, reclaiming land and building up new banks, thus reducing the river to the approximately uniform width of about 2,500 feet. It is proposed by this means to secure a channel depth of at least 8 feet at the lowest stage. The depth is now liable to become as little as 4 feet or even less in some places, and less than 8 feet in every place where the width is greater than 2,500 feet. Alluvial banks are to be protected from erosion. This general statement of the proposed application of the appropriation is as specific as the nature of the case will admit of. The changeable character of the river renders it impracticable to give in advance the exact localities where works will be required.

The work is located in the collection district of New Orleans.

Amount of revenue collected at the port of Saint Louis for the fiscal year ending June 30, 1883, was $1,393,744.56.

Money statement.

July 1, 1882, amount available		$112,145 18
Miscellaneous receipts		86 64
Amount appropriated by act passed August 2, 1882		600,000 00
		712,231 82
July 1, 1883, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1882	$510,995 09	
July 1, 1883, outstanding liabilities	5,991 15	
		516,986 24
July 1, 1883, amount available		195,245 58
Amount (estimated) required for completion of existing project		14,152,500 00
Amount that can be profitably expended in fiscal year ending June 30, 1885		1,000,000 00

Construction account.

Name of work.	Expended prior to July 1, 1882.	Expended during fiscal year ending June 30, 1883.	Total cost to June 30, 1883.
Piasa Island Dam	$32,333 30	.....	$32,333 30
Piasa Island Dam, removing	.....	$2,750 11	2,750 11
Alton Dam	33,623 92	.....	33,623 92
Alton Dike	33,324 70	34,000 00	67,324 70
Sawyer Bend protection	96,803 63	.....	96,803 63
Venice Dikes	36,341 85	.....	36,341 85
Arsenal Island protection	24,196 73	6,535 92	30,732 65
Closing Cahokia Chute	116,088 60	.....	116,088 60
Channel opposite Saint Louis	.....	40,873 88	40,873 88
Horsetail Bar:			
Dike 1	40,549 53	.....	40,549 53
Dike 2	23,600 26	.....	23,600 26
Dike 3	82,692 54	.....	82,692 54
Dike 4	41,290 11	.....	41,290 11

Construction account—Continued.

Name of work.	Expended prior to July 1, 1882.	Expended during fiscal year ending June 30, 1883.	Total cost to June 30, 1883.
Horsetail Bar:			
Dike 5	$30,933 87		$36,933 87
Training-wall	80,027 03		80,027 03
Primary hurdles, Secondary hurdles	304,389 33	$51,473 93	355,863 26
Twin Hollows, west bank:			
Primary hurdle, Secondary hurdle	103,500 25	93,136 91	196,637 16
Twin Hollows, east bank, bank protection	72,096 63	23,232 31	95,328 94
Beard's Island:			
Primary hurdle	7,166 24		7,166 24
Bank protection	28,448 29	55,810 47	84,258 76
Jim Smith's:			
Primary hurdle, Secondary hurdle	11,068 37	103,418 37	114,486 74
Pulltight:			
Primary hurdle, Secondary hurdle		46,465 47	46,465 47
Chesley Island, bank protection		47,401 39	47,401 39
Foster's Island, bank protection		5,779 18	5,779 18
Fort Chartres Dam	36,812 86		36,812 86
Turkey Island	24,463 85		24,463 85
Kaskaskia protection	66,465 62		66,465 62
Liberty Island:			
Dam	5,053 91		5,053 91
Protection	45,129 40		45,129 40
Devil's Island:			
Dike 1	65,871 17		65,871 17
Dam 1	49,848 58		49,848 58
Dam 2	16,678 30		16,678 30
Minton Point:			
Primary hurdle, Secondary hurdle	33,436 37		33,436 37
Cape Girardeau, primary hurdle	10,093 59	21,836 59	31,930 18
Cairo protection	119,868 66		119,868 66
	1,670,397 49	532,714 53	2,212,112 02

Property and material account.

Class of property.	Balance, July 1, 1882.	Debits.	Credits.	Balance, June 30, 1883.
Steamer Humphreys and expenses	$21,199 16	$22,723 45	$23,131 05	$20,791 56
Steamer Anita	2,910 22	7,191 32	10,101 54	
Steamer General Gillmore and expenses		22,081 46	221 21	21,860 25
Launch Hornet and expenses	106 56	1,383 97	1,383 97	106 56
Tug Mignon	4,077 72			4,077 72
Launch Florence and expenses		3,354 99	2,454 99	900 00
Barges, Barge Flats	82,507 37	14,437 75	34,837 75	62,107 37
Pile-drivers	55,420 83	12,810 28	18,413 96	49,817 15
Quarters, shops, &c	34,173 48	16,226 98	11,970 77	38,429 69
Quarter boats	7,525 98	202 30	1,452 30	6,275 98
Skiffs, &c	13,030 57	5,402 87	6,396 86	12,036 58
Tools and appliances	7,241 00	19,582 65	11,375 46	15,448 19
Hydraulic excavator	7,458 33	604 47	857 93	7,204 87
Ways for mattresses	5,711 09	585 53	964 03	5,331 69
Boarding outfit	12,358 95	5,382 36	2,676 24	15,065 07
Subsistence, &c	4,701 02	66,980 30	67,560 87	4,120 45
Photographic apparatus		785 28	445 77	339 51
Office furniture	913 36	522 35	258 50	1,177 21
Surveying instruments	1,751 86	44 65	364 85	1,431 66
Material:				
Brush	3,920 26	71,218 09	72,118 02	3,030 23
Piles	7,711 34	71,151 63	69,437 26	9,425 71
Stone	524 78	39,813 47	38,794 08	1,544 17
Miscellaneous	11,513 42	35,788 11	33,710 81	13,590 72
Brush, Minton Point	755 95	3,190 80	3,946 75	
Piles, Minton Point	2,134 55	1,177 36	3,311 91	
Stone, Minton Point	789 55	1,306 52	2,096 07	
Stone, Little Rock	1,581 09			1,581 99
Steamer Little Eagle, No. 2		5,255 25	5,255 25	
	290,028 34	420,205 00	423,539 10	295,694 33

Abstract of proposals for furnishing piles at Government works in Mississippi River between Saint Louis, Mo., and Harrisonville, Ill., received in response to advertisement dated December 15, 1882, and opened January 15, 1883, by Maj. O. H. Ernst, Corps of Engineers.

No.	Names and addresses of bidders.	3,500 piles, 30 to 35 feet.		5,000 piles, 35 to 45 feet.		1,500 piles, 45 to 60 feet.		Total.
		Price.	Amount.	Price.	Amount.	Price.	Amount.	
		Per ft.		*Per ft.*		*Per ft.*		
1	William H. Doza, Kaskaskia, Ill	$0 06	$6,300	$0 06	$10,500	$0 07	$4,725	$21,525
2	John Cleary, Chester, Ill	6½	6,825	7	12,250	8	5,400	24,475
3	Thomas A. Walker, Saint Louis, Mo.	7	7,350	7½	13,125	8	5,400	25,875
4	Ashton P. Johnson, Saint Louis, Mo.	7	7,350	8	14,000	9	6,075	27,425

Abstract of proposals for furnishing riprap on board Government barges in the Mississippi River within a distance of 100 miles from Saint Louis, Mo., received in response to advertisement dated December 15, 1882, and opened January 15, 1883, by Maj. O. H. Ernst, Corps of Engineers.

No.	Names and addresses of bidders.	25,000 cubic yards riprap.		Distance of quarry above Saint Louis or below Bushberg.	Amount added to bid for distance, at one-quarter cent per mile.	Price, as amended, for distance.	Total.
		Price.	Amount.				
		Per cubic yard.		*Miles.*	*Per cu. yd.*	*Per cu. yd.*	
1	Haas & Steins, Crystal City, Mo.	$0 50	$12,500	6	$0 01½	$0 51½	$12,875 00
2	Jas. Black, president, and J. S. Roper, secretary Grafton Quarry Company, Grafton, Ill.	48	12,000	38	9½	57½	14,375 00
3	John C. Salter, warden, Chester, Ill	47	11,750	51	12¾	59¾	14,937 50
4	Lorenz & Welge, Saint Louis, Mo	62	15,500			62	15,500 00
5	Wm. K. Patrick, Little Rock, Mo.	74	18,500	29	7¼	81¼	20,312 50

Abstract of proposals for furnishing annealed iron wire at United States Engineer Depot, foot of Arsenal street, Saint Louis, Mo., received in response to advertisement dated December 15, 1882, and opened January 15, 1883, by Maj. O. H. Ernst, Corps of Engineers.

No.	Names of bidders.	9,500 pounds wire No. 10.		22,500 pounds wire No. 12.		8,000 pounds wire No. 14.		Total.
		Price.	Amount.	Price.	Amount.	Price.	Amount.	
		Per lb.		*Per lb.*		*Per lb.*		
1	H. L. Fox & Co., Saint Louis, Mo.	$0 04 22/100	$407 55	$0 04 44/100	$999 00	$0 04⅞	$390 00	$1,796 55
2	Alfred Clifford, secretary and treasurer, Saint Louis, Mo.	4 4/5	418 00	4½	1,012 50	5	400 00	1,830 50
3	M. M. Buck & Co., Saint Louis, Mo.	4 35/100	413 25	4 63/100	1,035 00	5	400 00	1,848 25
4	Paul J. Field, Philadelphia, Pa.	5¼	494 00	5⅝	1,209 38	5¾	460 00	2,163 38

Abstract of proposals for furnishing spikes, iron, and nails at the United States Engineer Depot, foot of Arsenal street, in Saint Louis, Mo., received in response to advertisement dated December 15, 1882, and opened January 15, 1883, by Maj. O. H. Ernst, Corps of Engineers.

No.	Names of bidders.	17,000 pounds spikes, 8 by ½ inch.		11,000 pounds spikes, 6 by ½ inch.		2,000 pounds iron, ¾ inch diam.		3,200 pounds iron, ¾ inch diam.		800 pounds iron, ¾ inch diam.	
		Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.
		Per lb.		*Per lb.*		*Per lb.*		*Per lb.*		*Per lb.*	
*1	M. M. Buck & Co., Saint Louis, Mo	$0 03.15	$535 50	$0 04.15	$456 50	$0 02.8	$56 00	$0 02.6	$83 20	$0 02.4	$19 20
2	Waterman, Campbell & Co., Saint Louis, Mo	03.25	552 50	04.1	451 00	02.9	58 00	02.7	86 40	02.5	20 00
3	H. L. Fox & Co., Saint Louis, Mo	03.29	559 30	04.24	466 40	02.89	57 80	02.69	86 08	02.49	19 92
4	Ward & Brady, Saint Louis, Mo	03.15	535 50	04.1	451 00	03	60 00	02.8	89 60	02.6	20 80
5	E. E. Souther & Bro., Saint Louis, Mo	03.4	578 00	04.3	473 00	03	60 00	02.8	89 60	02.6	20 80
†6	Morris J. Lippman, Saint Louis, Mo	.....	.....	.....	.....	02.9	58 00	02.7	86 40	02.5	20 00

No.	Names of bidders.	14,000 pounds iron, ¾ inch diam.		500 pounds iron, ¾ inch diam.		30,000 pounds iron, 1 inch diam.		900 pounds nails, 10*d.*		2,600 pounds nails, 20*d.*		Total.
		Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	
		Per lb.		*Per lb.*		*Per lb.*		*Per lb.*		*Per lb.*		
*1	M. M. Buck & Co., Saint Louis, Mo	$0 02.3	$322 00	$0 02.3	$11 50	$0 02.2	$660 00	$0 03.5	$31 50	$0 03.5	$91 00	$2,266 40
2	Waterman, Campbell & Co., Saint Louis, Mo	02.4	336 00	02.4	12 00	02.3	690 00	03.6	32 40	03.6	93 60	2,331 90
3	H. L. Fox & Co., Saint Louis, Mo	02.39	334 60	02.39	11 95	02.29	687 00	03.35	30 15	03.35	87 10	2,340 30
4	Ward & Brady, Saint Louis, Mo	02.5	350 00	02.5	12 50	02.4	720 00	03.59	32 31	03.59	93 34	2,365 05
5	E. E. Souther & Bro., Saint Louis, Mo	02.5	350 00	02.5	12 50	02.4	720 00	03.8	34 20	03.8	98 80	2,436 90
†6	Morris J. Lippman, Saint Louis, Mo	02.4	336 00	02.4	12 00	02.3	690 00	.....	.....	.....	.....	1,202 40

*Rejected; sureties not certified. †Partial bid.

Abstract of proposals for furnishing rope, sisal yarn, and oakum at the United States Engineer Depot, foot of Arsenal street, in Saint Louis, Mo., received in response to advertisement dated December 15, 1882, and opened January 15, 1883, by Maj. O. H. Ernst, Corps of Engineers.

No.	Names of bidders.	1,826 pounds bolt rope, ⅞ inch diam.		1,190 pounds bolt rope, ¾ inch diam.		5,900 pounds bolt rope, 1 inch diam.		3,680 pounds bolt rope, 1¼ inch diam.		7,500 pounds bolt rope, 1½ inch diam.		6,640 pounds bolt rope, 1⅝ inch diam.	
		Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount	Price.	Amount.	Price.	Amount.
		Per lb.		*Per lb.*		*Per lb.*		*Per lb.*		*Per lb.*		*Per lb.*	
1	Udell, Schmieding & Co., Saint Louis, Mo..	$0 15.25	$278 46	$0 15.25	$181 47	$0 15.25	$899 75	$0 15.25	$561 20	$0 15 25	$1,143 75	$0 15.25	$1,012 60
*2	M. M. Buck & Co., Saint Louis, Mo.	15.2	277 55	15.2	180 88	15.2	896 80	15.2	559 36	15.2	1,140 00	15.2	1,009 28
3	Ward & Brady, Saint Louis, Mo	16.29	297 45	16.29	193 85	16.29	961 11	16.29	599 47	16.29	1,221 75	16.29	1,081 66
4	Samuel Cupples, Saint Louis, Mo.	16.25	296 72	16.25	193 37	16.25	958 75	16.25	598 00	16.25	1,218 75	16.25	1,079 00
5	Rowland A. Robbins, New York.	16.74	305 67	16.74	199 21	16.74	987 66	16.74	616 03	16.74	1,255 50	16.74	1,111 54
†6	W. H. Langdale, manager Anchor Line store, Saint Louis, Mo. ...	16.68	304 58	16.68	198 49	16.68	984 12	16.68	613 82	16.68	1,251 00	16.68	1,107 55

No.	Names of bidders.	3,615 pounds bolt rope, 1⅞ inch diam.		3,500 pounds sisal rope, ¾ inch diam.		5,000 pounds sisal rope, ½ inch diam.		12,000 pounds sisal rope, ¼ inch diam.		7,000 pounds sisal yarn, 2-ply.		2,000 pounds oakum.		Total.
		Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	
		Per lb.		*Per lb.*		*Per lb.*		*Per lb.*		*Per lb.*		*Per lb.*		
1	Udell, Schmieding & Co., Saint Louis, Mo.	$0 15.25	$551 29	$0 10	$350 00	$0 09 50	$475 00	$0 09.50	$1,140 00	$0 09.50	$665 00	$0 09.40	$188 00	$7,446 52
*2	M. M. Buck & Co., Saint Louis, Mo.	15.2	549 48	10	350 00	10	500 00	10	1,200 00	10	700 00	09.1	182 00	7,545 35
3	Ward & Brady, Saint Louis, Mo.	16.29	588 88	09.69	339 15	09.20	460 00	09.20	1,104 00	09.20	644 00	08.12½	162 50	7,653 82
4	Samuel Cupples, Saint Louis, Mo.	16.25	587 44	09.8	343 00	09.30	465 00	09.30	1,116 00	09.30	651 00	09	180 00	7,687 03
5	Rowland A. Robbins, New York.	16.74	605 15	09.95	348 25	09.45	472 50	09.45	1,134 00	09.45	661 50	08.94	178 80	7,875 81
†6	W. H. Langdale, manager Anchor Line store, Saint Louis, Mo....	16.68	602 98	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5,062 54

* No sureties. † Partial bid; no bidder's bond.

1.

REPORT OF MR. D. M. CURRIE, ASSISTANT ENGINEER.

SAINT LOUIS, MO., *July* 19, 1883.

SIR: I have the honor to transmit herewith the annual reports for the year ending June 30, 1883.

Part I. Upon works chargeable to the general appropriation for the "improvement of the Mississippi River between Cairo and the Illinois River."

Part II. Upon works chargeable to the appropriation for the "improvement of the channel of the Mississippi River opposite the city of Saint Louis, Mo."

Very respectfully, your obedient servant,

D. M. CURRIE,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

I.—*IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN CAIRO AND THE ILLINOIS RIVER.*

INTRODUCTION.

Localities.—In making the improvements under the general appropriation from Cairo to the Illinois River, to which these reports relate, work has been carried on at Arsenal Island, Horsetail Bar, Twin Hollows (west side), Twin Hollows (east side), Pulltight, Beard's Island, Chesley Island, and "Jim Smith's."

Organization.—The basis of the organization of the administrative staff in the field was adopted during the preceding year. At the close of this year the assignments of resident engineers and their assistants were:

At Arsenal Island, Mr. C. D. Lamb, assisted by Mr. Gerald Bagnall and Mr. E. F. Officer.

At Horsetail Bar, Mr. E. D. Libby, assisted by Mr. C. P. Mitchell and Mr. S. B. Cady.

At Twin Hollows, west side, Mr. W. S. Mitchell, assisted by Mr. J. L. Duffy.

At Twin Hollows, east side, Pulltight, and Jim Smith's, Mr. J. O. Holman, assisted by Mr. A. F. Frois and Mr. B. E. Johnson.

At Beard's Island, Mr. J. E. Savage.

At Chesley Island, Mr. C. V. Mersereau, assisted by Mr. J. W. Irwin.

The construction and repair of equipment at the supply depot was under the supervision of Mr. C. L. Stevenson, clerk; and Mr. J. L. Stubblefield, assistant engineer, acted as general receiver of materials on board the steamer General Gillmore.

Accompanying reports.—Reports of resident engineers, and the clerk at the supply depot, submitted herewith, are intended to form a part of this report, to which special reference is made for an historical account of the operations and statements of expenditures on account of labor and material in detail. All the assistants are entitled to credit for zealous devotion to their work, and faithful performance of duty.

ARSENAL ISLAND.

Field-work was resumed about the middle of August, after having been suspended from June 30 of the preceding year, because the island was submerged.

Low-water protection.—Sixty-five guide piles were driven and 1,003 linear feet of mattress constructed and placed in extending the low-water protection from Station 63 + 33 to Station 68 + 93, and in filling the gap from Station 54 + 50 to Station 59 + 10. These piles were spaced 15 feet between centers, and were driven in a curve that would pass through the mattress near its outer edge. The mattress protection was 40 feet wide, and a single section covered each of the spaces in which piles were driven.

Medium stage protection.—The medium stage protection of riprap stone was extended 3,328 feet from Station 36 + 40 to Station 69 + 68, but was carried to the full height—16 feet above standard low water—only from Station 38 + 90 to Station 42 + 20, having been left at 11 feet between Station 42 + 20 and Station 51, and between Station 51 and Station 69 + 38, and Station 36 + 40 and Station 38 + 90, at 8 feet above the same plane. The elevations were determined by the stages of water which prevailed at the time the work was in progress; the revetment being in each case such small height above the surface of the water as could be conveniently reached from the stone barge. The average width of the medium stage revetment placed during the year was 31.5 feet, or a total of 104,540 square feet.

During the lower stages of the river, the medium stage protection, which was placed during the flood stages of the preceding year, was redistributed, making the thickness uniform over the whole surface. This work was done between Station 1 and Station 36.

Reference is made to Plate I for locations, and to the report of Mr. C. D. Lamb, submitted herewith, for further details.

The expenditures aggregated $6,535 92, of which $6,194.07 was charged to the appropriation for improving the channel opposite the city of Saint Louis; and $341.85 to the general appropriation. The latter item was for labor.

HORSETAIL BAR.

Work was not entirely suspended at this locality during the prevalence of the flood stage, but the party of workmen was reduced to a single pile-driver crew, because all of the hurdle lines, except secondary No. 18, were submerged. This party worked on the repairs of No. 18, and made gates near the quarters on the west bank, for general use in repairs until the submerged lines were uncovered by the falling river about the last week of July. Additional working parties were then organized to resume the work of completing the repairs upon the primary line, which were under way when the flood came, to extend the line, to repair old and construct new secondary lines.

The lines from No. 18 to No. 30, inclusive, constructed during the years 1880 and 1881, had been injured by running ice during the winter, and by drift-wood during two flood seasons, to such an extent that they did not make an efficient obstruction to the flow of water, and a large body passed that way into the chute east of Carroll's Island at medium and high stages, with great velocity, preventing new and carrying away old deposits, threatening to reopen a passage that would deplete the navigable channel.

The plan adopted to make the obstruction efficient, included repairing and extending the primary line to connect with the bar on the head of Carroll's Island, at or above the stage of 16 feet above standard low water; repairing secondary lines Nos. 18, 23, 27, and 30, and constructing a line across the head of the chute.

Primary hurdles.—The east primary hurdle line was repaired from its head, near secondary No. 18, to its intersection with No. 30, in which 271 piles were driven, which is equivalent to the piling for 1,084 linear feet of hurdle; 750 linear feet of foundation mattress 50 feet wide, and 1,305 linear feet 30 feet wide, were constructed and placed; 2,512 linear feet of gates were placed, and 1,560 linear feet of fixed hurdles built. The width of the gates averages 18 feet, and the area equals 45,216 square feet. They were used above secondary line No. 25, and the length given includes all that were used between that point and the head of the primary line.

Fixed hurdles were used below secondary line No. 25. The length given completed the repairs to the lower end of the line, near its intersection with secondary No. 30. Of this, 200 linear feet between secondary lines Nos. 25 and 27 averaged 14 feet, and the remainder was 8 feet in width, making an area of 13,680 square feet.

Secondary hurdles.—Secondary hurdles were repaired. That of No. 18 was in progress July 1, and was continued until the 12th of August, when it was completed with the exception of bracing a small section in the gap near shore, which was done about the last of November. In these repairs 414 linear feet were rebuilt with piles, mattress, braces, and gates. Gates were placed 142 feet further, making 556 feet, and such piles as had become unserviceable upon 600 feet additional were replaced, making the pile-driving extend over 1,156 linear feet, and was equivalent to complete piling over 600 linear feet. The bracing extended over 1,090 linear feet, and the stringers over 1,240 linear feet.

The work on secondary line No. 23 consisted in driving 1,010 linear feet of piling, placing braces for 1,060 linear feet, hurdling 1,110 linear feet, and placing 150 linear feet of mattress. The hurdling averaged 15.5 feet in width, and was made by wattling the brush directly upon the piles.

On No 27, 1,650 linear feet were reconstructed so far as relates to piling, hurdling, and bracing, and upon 382 linear feet of this length a mattress 30 feet wide was placed. Of the hurdles, 1,270 linear feet, having a width of 16.6 feet, were wattled, and 380 linear feet, of which the width was 19.5 feet, were curtain hurdles.

Work was begun on secondary line No. 30 November 23, and continued till the close of the season, December 6. About 1,200 linear feet of the line were reconstructed with piling, bracing, and stringers, 120 linear feet of foundation mattress constructed and sunk, and 1,760 linear feet of wattling placed.

Carroll's Island hurdle.—The construction of this line was begun on the 26th of March, and was continued until June 18, with the exception of about twelve days between May 22 and June 4, when the stage of the river was above the piling. The length of the line was determined when preparing to begin work and found to be 2,450 feet. The head of the island was afterwards eroded, which may extend it to 2,700 feet. Of this, however, nothing definite can be said, for deposits began to fill the space which had been eroded as soon as the river commenced falling—about the close of the year.

Piles were driven for the whole of the original length of the line; 2,350 linear feet of foundation mattress 46 feet wide were placed, extending up from the lower end of

the line, and the wattling was completed upon 1,625 linear feet, an average depth of about 11 feet.

Stringers were placed upon 2,092 feet of the drift row and 850 feet of the main row, and diagonal braces were placed 850 feet upon each of these two rows. Cross braces were placed for a distance of 437 linear feet from the island end.

Reference is made to Plate II for locations, and to the report of Mr. E. D. Libby, submitted herewith, for further details.

The expenditures aggregated $51,473.93, distributed as shown in the accompanying statement:

STATEMENT OF EXPENDITURES AT HORSETAIL BAR FOR THE FISCAL YEAR ENDING JUNE 30, 1883.

Primary hurdle:		
Labor	$2,932 52	
Piles	1,134 28	
Brush	2,102 63	
Stone	946 11	
Rope	200 09	
Wire	16 05	
Nails	16 80	
Spikes	30 08	
Lumber	407 66	
Bolts	1,020 82	
Subsistence	2,189 56	
Steamer Humphreys	112 40	
Pile-drivers	354 56	
Barges	6 24	
Quarters	119 70	
Small boats	83 00	
Tools and appliances	162 20	
		$11,834 70
Secondary hurdles:		
Labor	4,515 15	
Piles	2,246 91	
Brush	1,716 67	
Stone	225 34	
Rope	210 43	
Wire	21 40	
Iron	4 54	
Nails	7 20	
Spikes	41 36	
Lumber	83 93	
Bolts	561 58	
Subsistence	2,496 24	
Steamer Humphreys	219 18	
Pile-drivers	859 52	
Quarters	228 90	
Small boats	96 28	
Tools and appliances	191 60	
		13,726 29
Carroll's Island hurdle:		
Labor	3,163 94	
Piles	3,360 02	
Brush	2,529 47	
Stone	720 00	
Rope	196 23	
Iron	2 60	
Wire	72 25	
Spikes	42 66	
Bolts	273 59	
Subsistence	2,552 41	
Steamer Humphreys	206 50	
Steamer Gillmore	200 00	
Launch Hornet	51 20	
Launch Florence	9 78	
Pile-drivers	1,043 01	
Barges	858 13	
Quarters	1,248 41	
Small boats	820 17	
Tools and appliances	1,090 88	
		18,441 25

Bank protection, head of Carroll's Island:		
Labor	$263 71	
Piles	43 76	
Brush	130 05	
Stone	99 22	
Rope	12 86	
Wire	8 92	
Nails	2 56	
Spikes	5 56	
Subsistence	166 64	
Steamer Humphreys	16 52	
Pile-drivers	44 03	
Barge flats	63 96	
Quarters	64 77	
Small boats	41 44	
Tools and appliances	54 88	
		$1,018 88
Engineering and contingences:		
Engineering	2,671 04	
General expense	2,042 11	
Telephone	313 48	
Office furniture	12 17	
Instruments	33 01	
Boarding outfits	17 71	
Contingencies	1,359 23	
Surveys	4 06	
		6,452 81
		51,473 93

TWIN HOLLOWS, WEST SIDE.

Work at this locality was in progress continuously from July 1 until the season was closed by the severe weather which followed the storm of December 6; resumed March 1, and continued to June 17, when the flood stage to which the river had risen prevented further active field operations. A small party was retained to care for property, including a crib which had been completed and was waiting for a favorable opportunity to be placed.

During the first half of the year the number of persons engaged was limited to that which could be profitably employed within the limits available for work without interfering with the navigable channel, which at the beginning of the year crossed the primary line about Station 90, and continued to the west shore; thence rebounding struck Beard's Island above Station 36; afterwards moving slowly down stream until at the end of November its line of greatest depth and velocity crossed the primary about Station 130; then swinging through a small arc, recrossed the line and continued to the foot of Beard's Island. To keep pace with this movement and leave the navigable channel free from obstructions, the rate of progress of the work was retarded through July, increased during August, and decreased again the 1st of September, after which it was continued slowly, keeping the head of the primary line in the margin of the channel, and building secondary lines fast enough to have each completed soon after the primary had reached the point of intersection.

The number of persons employed ranged between 100, July 1, and 300, September 1, then reduced to about 140, which number was employed until the end of the season, with the exception of a small reduction made after the middle of October by sending men to repair works at Pulltight.

During the second half of the year the amount of funds available confined operations to parts of works which were under process of construction and to repairs of lines which were damaged by ice at the breaking of the winter's gorges.

Primary hurdles.—The gaps in the primary line which existed at the close of the preceding year were closed and the line extended to Station 122+50. Of this distance piling was driven for 2,005 feet; foundation mattress, 50 feet wide, placed upon 4,075 feet, and 3,860 linear feet wattled an average depth of 13 feet.

The fixed hurdles closed the gaps below Station 6+20 and extended the line to Station 94, and from 104 to Station 122+50.

Willows.—The space between stations 94 and 104 was occupied by a high sand-bar, which was dry when the work in that vicinity was in progress. Willows were planted upon the upper half of it, and the balance was protected by a mattress.

Cribs.—In both primary and secondary lines cribs were substituted for piling where the earth on the bed-rock was not deep enough to hold piles.

Of these there were constructed and placed: In the primary line, 250 linear feet, above Station 6+20. In secondary No. 1, 270 linear feet; No. 2, 300 linear feet; No

3, 175 linear feet; No. 4, 600 linear feet constructed, of which 410 feet were placed; No. 5, 300 linear feet.

Secondary hurdles.—Secondary hurdles Nos. 1 to 3, inclusive, were completed during the first half of the year. In Nos. 4 and 5 passage ways were left for an entrance to the sheltered basin of deep water found under No. 3, which had been selected for harboring the plant during the winter.

During the second half of the year work was carried on, which had for its object the completion of these lines and repair of the gaps made by the ice.

There were completed during the year: in line No. 1, piling and foundation mattress each 570 feet, wattling 840 feet; No. 2, 270 feet of piling and foundation mattress, 570 feet of wattling; No. 3, 1,020 linear feet of piling, 873 linear feet of mattress, and 605 linear feet of wattling; No. 4, 300 linear feet each of piling and mattress, and 840 feet of wattling; No. 5, 1,340 linear feet each of piling and mattress, and 1,640 linear feet of wattling.

The entire length of piling was braced. The width of the foundation mattresses averaged 30 feet, and the depth of wattling 13 feet.

Protecting deposits.—A low-water mattress having a width of 104 feet was constructed and placed just outside the primary line, extending from shore, near the origin of the line, to Station 16+45.

It was constructed during the fall season, and was designed to protect the deposits which had been secured.

Reference is made to Plate III for locations, and to the report of Mr. W. S. Mitchell, submitted herewith, for further details.

Expenditures aggregated $93,136.91, distributed as shown in the accompanying statement:

STATEMENT OF EXPENDITURES AT TWIN HOLLOWS, WEST SIDE, FOR THE FISCAL YEAR ENDING JUNE 30, 1883.

Primary hurdles:		
Labor	$5,574 79	
Piles	4,136 63	
Brush	3,799 94	
Stone	1,460 77	
Rope	64 13	
Wire	192 60	
Nails	2 40	
Spikes	53 48	
Bolts	322 95	
Subsistence	6,500 50	
Steamer Humphreys	421 50	
Launch Hornet	348 00	
Pile-drivers	1,237 76	
Barges	78 00	
Quarter boats	133 95	
Quarters	266 70	
Small boats	209 62	
Tools and appliances	412 05	
		$25,215 77
Crib primary line:		
Labor	1,150 44	
Piles	422 50	
Stone	474 48	
Rope	16 24	
Spikes	6 68	
Bolts	181 01	
Subsistence	664 00	
		2,915 35
Secondary hurdle:		
Labor	5,965 87	
Piles	4,200 76	
Brush	3,331 96	
Stone	308 40	
Rope	22 66	
Wire	274 32	
Nails	19 49	
Spikes	21 35	
Bolts	464 83	
Subsistence	5,700 53	
Steamer Humphreys	393 40	
Launch Hornet	344 83	

Pile-drivers	$1,762 54	
Barges	71 76	
Barge flats	102 33	
Quarter boats	128 25	
Quarters	457 82	
Small boats	409 62	
Tools and appliances	912 05	
		$24,892 77
Crib secondary line:		
Labor	5,263 78	
Piles	2,495 14	
Brush	214 57	
Stone	855 03	
Rope	79 34	
Wire	15 27	
Nails	10 48	
Spikes	124 55	
Bolts	776 23	
Lumber	1,002 72	
Subsistence	5,044 00	
Miscellaneous supplies	36 87	
Steamer Humphreys	132 16	
Steamer Gillmore	200 00	
Launch Florence	81 50	
Pile-drivers	1,278 06	
Barges	1,560 78	
Barge flats	1,300 52	
Quarter boats	91 28	
Quarters	1,800 00	
Small boats	672 48	
Tools and appliances	968 04	
		24,002 80
Low-water protection:		
Labor	1,565 70	
Piles	113 41	
Brush	2,690 06	
Stone	431 21	
Rope	7 67	
Wire	187 25	
Nails	7 20	
Spikes	48 88	
Bolts	6 02	
Subsistence	1,391 12	
Steamer Humphreys	50 58	
Steamer Hornet	46 40	
Pile-drivers	49 28	
Barge flats	303 65	
Quarters	90 30	
Small boats	69 88	
Tools and appliances	137 34	
		7,195 95
Engineering and contingencies:		
Engineering	3,747 47	
General expense	3,852 22	
Telephone	677 95	
Office furniture	26 50	
Surveys	11 60	
Instruments	67 84	
Contingencies	530 69	
		8,914 27
		93,136 91

TWIN HOLLOWS, EAST SIDE.

The work of protecting the bank at this locality was in progress at the beginning of the year, and was continued during the flood of July. The operations were confined to the fabrication of mattresses, until the river had subsided to stages suitable for placing the medium stage protection.

Low-water protection.—The section of low-water mattress which had been fabricated at the beginning of the year was extended to a length of 1,500 feet, and held until

the flood began to subside, when it was successfully placed. Another section 1,210 feet long was constructed and placed, which completed the low-water protection from Station 0 to Station 86.

Medium stage protection.—The zone between standard low water and 16 feet above that plane, was not in condition to receive complete revetment, the upper portion being too steep to retain stone. The protection was made continuous between Station 0 and Station 86, but its height was irregular, conforming to that of the slope suitable to receive it.

Of this protection, all except 200 feet between Stations 59 and 61 was placed during the fall season, and finished on the 19th of October. The bank upon the section between Stations 59 and 61 was vertical at the time the other work was done, and its protection was delayed so that it might be graded by the action of the river. This was done and the protection was placed here about the middle of May.

Reference is made to Plate IV for locations, and to the report of Mr. J. O. Holman, submitted herewith, for further details.

The expenditures aggregated $23,232.31, distributed as shown in the accompanying statement:

STATEMENT OF EXPENDITURES AT TWIN HOLLOWS, EAST BANK, FOR THE FISCAL YEAR ENDING JUNE 30, 1883.

Low-water protection:		
Labor	$3,249 99	
Piles	310 08	
Brush	3,023 51	
Stone	885 12	
Rope	325 75	
Wire	294 25	
Nails	43 20	
Spikes	75 20	
Subsistence	2,320 68	
Steamer Humphreys	134 50	
Pile-drivers	103 04	
Barges	184 08	
Barge flats	75 80	
Quarters	147 00	
Ways	182 00	
Small boats	75 70	
Tools and appliances	173 50	
		$11,603 40
Grading:		
Labor	165 99	
Subsistence	53 28	
Excavator	76 20	
		295 47
Medium stage protection:		
Labor	1,087 36	
Piles	75 48	
Brush	1,199 90	
Stone	5,421 56	
Rope	7 67	
Wire	26 75	
Subsistence	1,875 87	
Steamer Humphreys	118 02	
Pile-drivers	42 24	
Quarters	69 33	
Quarter boats	28 50	
Small boats	37 85	
Tools and appliances	86 76	
		10,077 29
Engineering and contingencies:		
Engineering	371 22	
General expense	701 16	
Telephone	103 83	
Survey	3 43	
Office furniture	3 97	
Instruments	10 42	
Contingencies	62 12	
		1,256 15
		23,232 31

PULLTIGHT.

The work at this locality had for its object the closing of the small chute east of Beard's Island, and was begun soon after the 1st of July. It consisted of a line of primary hurdles, supported by secondary lines, and the protection of a portion of the head of the Willow Bar above Beard's Island.

Primary hurdle.—The primary line projected from the shore at Station 113 of the line of reference, which has its origin at the head of the revetment at Twin Hollows, east side, crossed to the deep water found near shore to a bar which was dry at a stage 16 feet above standard low water, upon a line located with special reference to economy in constructing and maintaining the works.

Piles had been driven and stringers placed to the bar, a distance of 2,860 feet from the shore, foundation mattress placed upon 2,700 feet, bracing upon 2,425 feet, and wattling upon 1,100 feet of the line—measured in each case from shore. When work was suspended, June 8, on account of the high stage of the water, the average width of the mattress constructed was 40 feet, and the average depth of the wattling 15 feet. The location of this hurdle below its intersection with the bar has not been definitely determined, but will be upon the most direct and economical line to the head of the Willow Bar previously mentioned.

Secondary hurdles.—No. 3 was constructed across the head of the chute during July and August, at a distance of about 4,200 feet from the origin of the primary line. This hurdle was about 850 feet long and averaged 10 feet in depth, having an area of 8,500 square feet.

Line No. 1 was extended 200 feet from shore; only the piling was driven.

Bank protection.—Two mattresses were constructed during the month of May to protect the bank just above and below the shore end of the primary hurdle line. The former of these was 290 feet long by 45 feet wide, and the latter 145 feet by 25 feet.

Another mattress was commenced in June to protect the head of the Willow Bar above Beard's Island, a section 100 feet long by 58 feet wide has been constructed and placed at the time operations were suspended in that month.

Reference is made to Plate III for locations, and to the report of Mr. J. O. Holman, submitted herewith, for further details.

The expenditures aggregated $46,465.47, distributed as shown in the accompanying statement:

STATEMENT OF EXPENDITURES AT PULLTIGHT FOR FISCAL YEAR ENDING JUNE 30, 1883.

Primary hurdle:

Labor	$6,217 64	
Pile timber	6,595 96	
Brush	5,798 03	
Stone	1,886 48	
Rope	147 11	
Wire	140 46	
Nails	13 41	
Spikes	74 00	
Bolts	472 68	
Iron	.43	
Subsistence	5,032 61	
Steamer Humphreys	371 52	
Steamer Gillmore	210 00	
Launch Hornet	69 60	
Launch Florence	716 23	
Pile-drivers	1,773 21	
Quarters	1,747 27	
Barge flats	959 40	
Skiffs	650 60	
Tools, &c	1,065 30	
		$33,941 94

Secondary hurdle:

Labor	2,217 19	
Pile timber	1,060 44	
Brush	1,088 83	
Stone	303 05	
Rope	23 01	
Wire	37 45	

Nails	$1 20	
Spikes	11 28	
Bolts	24 08	
Subsistence	1,220 27	
Steamer Humphreys	106 44	
Steamer Gillmore	50 00	
Launch Florence	13 04	
Barge flats	53 30	
Pile-drivers	325 11	
Quarters	100 86	
Skiffs	43 91	
Tools	86 76	
		$6,766 22
Engineering and contingencies:		
Engineering	2,542 39	
General expense	1,868 72	
Surveys	2 95	
Telephone	377 04	
Office furniture	18 16	
Instruments	46 72	
Contingencies	901 33	
		5,757 31
		46,465 47

BEARD'S ISLAND.

Low-water protection.—In continuation of the revetment of the west bank of this island 4,850 linear feet of low-water mattress of the standard width of 120 feet, and 325 linear feet, 100 feet wide, were constructed. Of the standard width mattress only about 3,600 linear feet was successfully placed, protecting 3,500 linear feet of bank, between Stations 35 + 50 and 70 + 50. The difficulties encountered between Stations 35 + 50 and 49 + 75 were excessive, being made so by the peculiar configuration of the water-way and bars in the vicinity. The channel was in a state of transition, and the axis of greatest velocity, crossed from the bluffs at the beginning of July, as shown in the map of the locality, plate V, striking the bank at Station 30, the point at which the low-water mattress was then under process of construction. The lower reef projecting from the Missouri shore threw nearly the whole volume of the river against the island through a funnel-shaped stream, of which the lower orifice was not more than 350 feet wide during a period of several days with the river about 6 feet above standard low water.

The point of impact moved continuously down stream at about the same rate that the construction of the low-water mattress progressed, keeping the force which opposed the construction and sinking of the mattress at a maximum.

The slow progress made in completing the low-water protection may be traced in part to the deep, swift water crossing the line under an obtuse angle, and in part to the drift-wood brought in contact with the mattress during the flood of July.

Medium stage protection.—Medium stage protection was extended from Station 16 + 50 to Station 18, and from Station 28 to 65, except a section 50 feet long below Station 35, and another 300 feet in length between Stations 59 and 62, by a revetment of riprap stone. The total length thus protected was 3,500 feet, and of this amount 850 feet between Stations 16 + 50 and 18, Stations 28 and 33, and from 40 + 50 to Station 42 + 50 was carried to the required height—16 feet above standard low water—and the remainder was only carried to 6 feet above that plane.

A medium-stage mattress 600 feet long by 60 feet wide was placed between Stations 44 and 50, and another 900 feet long and averaging 80 feet in width between Stations 64 and 73. The latter was supplemented by the 100-foot wide mattress previously mentioned.

Grading.—Grading by the hydraulic excavator was begun below Station 35 and carried a distance of 1,043 feet. Its object was to reduce a steep bank varying from 14 to 20 feet in height to a uniform grade of 2 to 1, to facilitate the placing of riprap protection.

This class of work was carried on less than a month, but the results were satisfactory.

[f] Reference is made to Plate V for locations, and to the report of Mr. J. E. Savage, submitted herewith, for further details.

The expenditure aggregated $55,810.47, distributed as shown in the accompanying statement:

STATEMENT OF EXPENDITURES AT BEARD'S ISLAND FOR THE FISCAL YEAR ENDING JUNE 30, 1883.

Low-water protection:		
Labor	$9,479 41	
Piles	1,391 25	
Brush	13,993 48	
Stone	2,093 71	
Rope	70 70	
Wire	497 55	
Iron	9 08	
Nails	19 20	
Spikes	56 40	
Bolts	34 40	
Subsistence	8,409 68	
Steamer Humphreys	826 14	
Steamer Anita	32 12	
Launch Florence	35 72	
Pile-drivers	438 40	
Barges	399 36	
Barge flats	132 20	
Quarters	548 10	
Ways	502 65	
Small boats	327 64	
Tools and appliances	654 39	
		$39,951 58
Grading:		
Labor	389 40	
Subsistence	370 36	
Excavator	380 41	
Small boats	14 00	
Tools and appliances	28 00	
		1,132 17
Medium stage protection:		
Labor	2,297 90	
Piles	477 22	
Stone	3,828 22	
Rope	120 06	
Spikes	48 88	
Subsistence	2,026 60	
Steamer Humphreys	230 42	
Launch Florence	9 40	
Quarter-boats	42 75	
Quarters	50 40	
Small boats	78 12	
Tools and appliances	156 23	
		9,366 20
Engineering and contingencies:		
Engineering	1,328 00	
General expense	2,055 09	
Telephone	306 24	
Surveys	9 86	
Office furniture	11 47	
Instruments	25 34	
Contingencies	1,574 52	
		5,310 52
		55,810 47

CHESLEY ISLAND.

Low-water protection.—The revetment of this island was begun about the 20th of September and continued until the 5th of December, when 4,464 linear feet of bank between Stations 0, and 44+64 had been protected by placing a mattress 120 feet wide with its inside edge as nearly as practicable in the curve of standard low water. Of this, 4,305 linear feet were constructed and placed in a single section in water varying from 24 to 30 feet in depth, and flowing swiftly, say with a surface velocity of 5 feet per second. This section could have been continued an indefinite length, and was terminated by the completion of the work to the point at which the channel leaves the high ground of the island.

The remaining 164 feet were protected by a section recovered from a wreck of one of the mattresses at Beard's Island, which was landed here by the steamer Humphreys and was afterwards floated to lower end of this protection and placed as a part of it.

This becomes the longest section of mattress in the world. It was constructed and placed with only a single small break which occurred about Station 20, but did not destroy the efficiency of the protection even upon the space that it occupied.

The entire section of 4,305 linear feet was constructed in fifty-six working days, of which thirty were reckoned at ten hours and the remainder at nine hours, but upon twenty of these days the party consisted of not more than twenty workmen, or less than one-third of a full force. The exact time spent upon the mattress was 28,015 hours; calling sixty laborers a full party this would be equivalent to forty-seven working days of ten hours each, and would make the daily average 94 feet. This rate was exceeded upon several days, and could be maintained indefinitely where the difficulties were not excessive if the party could be kept full. This seems impracticable, however, except by having a reserve from which the party can be filled at pleasure: and this can be done only when other works are in progress under the same supervision.

Medium stage protection.—Extending the protection up to the plane of 6 feet above standard low water followed the placing of the low water mattress closely, leaving only room enough between for movements of barges used in connection with the work.

It reached Station 39 at the close of the fall season, and during the second half of the year it was raised to 16 feet above standard low water to a distance of 3,475 feet below Station 0, at the head of the island.

Protection of the head of the island.—The protection was extended around the head of, and upon the opposite side of the island to Station 5+85, measured from the zero station of the original line. The mattress for this protection was an average of 40 feet in width, and the riprap protection extended to 14 feet above standard low water.

A medium stage mattress about 400 feet long by 50 feet wide was built and placed as an additional protection to the head of the island and to prevent the undermining of the upper end of the low-water mattress. It extends up-stream from the head of the latter.

Grading.—Grading by the hydraulic excavator was completed from the head of the island—Station 0 to Station 27+60.

The bank was about 18 feet above the water's surface at 6 feet above standard low water, and was excavated to a slope of 2 to 1, which gives about 12 cubic yards per linear foot, or about 33,000 cubic yards excavated in all.

Hurdles.—A hurdle line about 900 feet long to cross the chute west of the island was commenced April 18, and work continued on it until operations were stopped by high water June 15. Its location was about 700 feet below the mouth of Meramec River and 1,000 feet below the head of the island.

Piles were driven for 800 feet of the line, leaving a gap of about 100 feet near the middle. Of this, 720 linear feet was furnished with foundation mattress, and 250 feet with longitudinal stringers.

Reference is made to Plates III and VI for locations, and to the report of Mr. C. V. Mersereau, submitted herewith, for further details.

The expenditures aggregated $47,401.39, distributed as shown in the accompanying statement:

STATEMENT OF EXPENDITURES AT CHESLEY ISLAND FOR THE FISCAL YEAR ENDING JUNE 30, 1883.

Low-water protection:

Labor	$4,278 59	
Piles	930 63	
Brush	8,946 93	
Stone	1,419 25	
Rope	120 73	
Wire	387 72	
Nails	19 36	
Spikes	210 47	
Subsistence	3,763 44	
Steamer Humphreys	202 32	
Steamer Anita	8 03	
Pile-drivers	298 41	
Barges	246 48	
Quarters	563 45	
Ways	280 28	
Small boats	147 31	
Tools and appliances	373 01	
		$22,196 41

Grading:		
Labor	$294 03	
Subsistence	189 86	
Excavator	375 92	
		$859 81
Medium stage protection:		
Labor	691 32	
Piles	38 10	
Brush	467 25	
Stone	8,027 70	
Rope	5 30	
Wire	21 40	
Subsistence	1,338 15	
Steamer Humphreys	67 44	
Pile-drivers	82 56	
Quarters	488 35	
Small boats	69 37	
Tools and appliances	330 21	
		11,627 15
Hurdle:		
Labor	1,239 94	
Piles	1,324 02	
Brush	887 50	
Stone	600 27	
Rope	19 25	
Wire	17 84	
Nails	2 56	
Spikes	16 70	
Bolts	6 25	
Subsistence	1,242 28	
Steamer Humphreys	16 52	
Steamer Gillmore	120 00	
Pile-drivers	628 32	
Quarters	759 46	
Small boats	133 64	
Tools and appliances	740 88	
		7,755 43
Engineering and contingencies:		
Engineering	1,766 74	
General expense	1,481 98	
Telephone	526 88	
Survey	3 48	
Office furniture	20 66	
Instruments	53 02	
Contingencies	1,109 83	
		4,962 59
		47,401 39

JIM SMITH'S

The work of construction at this place was suspended, on account of high water from the 1st to the 17th of July, when it was resumed upon the primary line at Station 9 on the branch from F to F, and continued to the close of the working season, December 6, since which time no work of construction has been done.

Primary hurdle.—The primary hurdle was under process of construction from the date of resumption until the close of the fall season, and during that time was extended from Station 9 to Station 34 on the branch F F, and in addition piles were driven to Station 35+50.

The branch F E was completed from Station 53 to 77 and in addition piles were driven from Station 41 to 53, and from Station 77 to 86+50. Foundation mattress was constructed and placed for 5,800 feet between Stations 9 and 35 on the branch F F, and between Stations 50 and 82, on the main line from F to E. Bracing was placed on 6,420 feet, and stringers on 1,010 additional feet, or a total length of 7,430 feet. The average depth of wattling was 22 feet, making 107,800 square feet.

Late in the season the water which found an outlet east of the large middle bar lying upon both sides of the primary line, concentrated into a narrow passage, swept the inclined branch from Station 10, cut the bar away to F, and damaged the line to the extent of scouring out piles upon 150 feet of its length from Station 34 to 35 + 50

and eroded to dangerous depths upon the entire distance. These breaks were rebuilt, a mattress was placed to prevent the erosion of the bar in the vicinity of F, and another was begun about Station 14 on the branch line F F but was suspended when only 150 feet had been built.

Willows.—Willows were planted in four rows and cottonwood in one, from Station 0 on the main line to Station 33 upon a bar which became dry throughout its entire length at 10 feet above standard low water, and of which the highest point was uncovered when the declining river reached 13.5 feet above that plane.

Secondary hurdles.—Secondary hurdles were under process of construction from the day on which they were commenced in July to the close of the fall season with the following results:

Line No. 1, which was begun in July, was completed with piling, bracing, stringers, mattress, and wattling. Its length was 870 feet.

Line No. 2 was completed from shore to a distance of 1,890 feet, and of these were duplicated 500 feet of piling, 450 feet of mattress, and 450 feet of stringers, in repairing breaches.

Line No. 3, was completed as follows: Piles were driven, and stringers, braces, and mattress placed for 1,445 feet, of which 1,195 feet were wattled.

Line No. 4 was completed to a distance of 575 feet from shore.

Line No. 5 was completed. Its length was 1,050 feet.

Line No. 6 was completed to a distance of 750 feet from the primary line, whence a bar, dry at medium stages, extended to the high bank.

Summing up the work done upon secondary lines Nos. 1 to 6, inclusive, their results: Piles driven for 7,600 feet; mattress and stringers, each placed upon 7,550 feet; braces upon 6,580 feet of line, and 6,330 feet were wattled.

Reference is made to Plate III for locations, and to the report of Mr. J. O. Holman, submitted herewith for further details.

The expenditures aggregated $103,418.37, distributed as shown in the accompanying statement:

STATEMENT OF EXPENDITURES AT JIM SMITH'S FOR THE FISCAL YEAR ENDING JUNE 30, 1883.

Primary hurdle:

Labor	$13,861 63	
Piles	7,780 72	
Brush	7,415 66	
Stone	2,262 52	
Rope	755 45	
Wire	283 55	
Iron	27 24	
Nails	16 80	
Spikes	131 60	
Lumber	85 92	
Bolts	1,218 62	
Subsistence	13,493 76	
Steamer Humphreys	393 40	
Steamer Anita	136 51	
Launch Florence	317 72	
Pile-drivers	2,058 24	
Barge flats	83 38	
Quarters	826 33	
Quarter boats	25 65	
Small boats	421 08	
Tools and appliances	815 20	
		$52,416 98

Secondary hurdle:

Labor	10,943 76
Piles	7,677 30
Brush	4,307 92
Rope	333 45
Wire	171 20
Stone	1,497 30
Iron	18 16
Nails	9 60
Spikes	86 48
Lumber	95 92
Bolts	1,269 36
Subsistence	10,401 69

Steamer Humphreys	$309 10	
Launch Florence	167 32	
Pile-drivers	2,094 15	
Quarters	644 70	
Quarter boats	22 85	
Small boats	315 81	
Tools and appliances	611 43	
		$40,976 90
Engineering and contingencies:		
Engineering	1,777 50	
Contingencies	4,239 97	
General expense	3,408 45	
Surveys	16 48	
Telephone	511 46	
Office furniture	19 59	
Instruments	51 04	
		10,024 49
		103,418 37

SUPPLY DEPOT.

Depot fenced.—A board fence was constructed to separate the depot yard from the thoroughfare for footmen, along the line of Iron Mountain and Southern Railroad. The fence covered the whole front, 900 feet in length, but by connecting the outside walls of the store-rooms and other permanent buildings the length necessary to be constructed was reduced to 521 feet. The expenditures on account of labor and materials for this fence, which are the only expenditures chargeable to the supply depot, were, for labor, $76.18; for material, $84.16.

Additions to plant.—The plant was increased by adding one tow-boat, General Gillmore; three barge-flats, Nos. 57, 58, and 59; seventy-six sections of portable shanties for mess-rooms, kitchens, quarters, and store-rooms; four small portable shanties, one wharf-boat, one floating machine shop, and nineteen hurdling flats. Of these the *General Gillmore* was built on the Ohio River; and had only the fitting for an electric light and other minor work done at the depot. The barge flats were coal barges which were purchased and altered to make them suitable for the transportation of material on deck. The sections of portable shanties for quarters, small shanties, and hurdling flats were constructed at the depot from material purchased. The machine shop and wharf-boat were built at the depot upon hulls of pile-drivers which had become unserviceable for driving piles.

Extraordinary repairs.—The following-named vessels received considerable repairs: Tow-boat A. A. Humphreys, launches Florence and Hornet, pile-drivers Nos. 3 and 5, barges 12 and 23, and barge flats Nos. 32, 49, and 51.

Ordinary repairs.—The following received ordinary repairs: Barges Nos. 9, 10, 13, 14, 16, 17, 20, 22, 25, 26, and 27; barge-flats Nos. 28, 33, 34, 38, 40, 42, 54, 57, 58, and 59; mattress-barge No. 3; quarter-boats Nos. 2, 4, and 6; the wharf-boat and small boats.

Material.—All of the smaller material, such as rope, iron, wire, nails, and spikes and the miscellaneous material used in the different works were stored at the supply depot and issued as needed. In addition to handling and shipping this material, 20,845 bolts were constructed of assorted sizes for use at the localities where work of improvement is being carried on.

Reference is made to the report of Mr. C. L. Stevenson, submitted herewith for further details.

PROCURING MATERIALS.

During the first half of the year each class of material was procured as in the preceding year. Piles, stone, rope, wire, iron, nails, and spikes, were procured by purchase in open market. The piles were usually delivered at the works in rafts, but occasionally on barges; the cost of delivery being included in the price paid. Stone was delivered on barges belonging to the United States at quarries operated by the persons who furnished it. Rope, wire, iron, nails, and spikes were purchased in open market and delivered to the supply depot.

During the second half of the year the purchase in open market yielded to contracts the delivery of each class remaining as before.

Brush continued to be procured by hired labor and purchase of royalty.

All the works were supplied from a common stock. The quantity of each class expended and on hand is shown in the appended table.

Statement showing quantities of material expended during the fiscal year ending June 30, 1883, and on hand at its close.

Kind.	Expended.	On hand June 30, 1883.
Piles, assorted sizes ..... number..	19, 625	3, 309
Brush ..... cords..	26, 065. 1	931. 8
Stone ..... cubic yards..	38, 796. 8	1, 296. 9
Rope, sisal, assorted sizes ..... pounds..	32, 739	42, 234
Wire, assorted sizes ..... do...	54, 006	66, 395
Iron, assorted sizes ..... do...	68, 402	56, 449
Nails, assorted sizes ..... do...	17, 078	17, 023
Spikes, assorted sizes ..... do...	34, 240	35, 763
Bolts, assorted sizes ..... do...	12, 435	3, 071
Lumber ..... feet..	472, 603	79, 284

PLANT.

The plant available for use in connection with the works in this vicinity was freely transferred between localities as needed. It was increased during the year by the addition of one tow-boat, seven model barges, ten barge flats, three pile-drivers, twenty-six buildings for portable quarters, forty-one small boats, and tools and appliances. Of these three barges flats were converted from coal flats which were purchased, and nineteen small flats and twenty-two portable buildings were built from material purchased.

The others were returned from works carried on in the vicinity of Cape Girardeau and at Alton Harbor, and of these the Anita was dismantled and her machinery used in the construction of the new tow-boat General Gillmore.

The plant thus increased and concentrated is adapted to the employment of two thousand laborers and to the expenditure of $1,000,000 per annum.

INFLUENCES OF RIVER STAGES AND WEATHER.

Prevailing stages.—The river remained below the stage of 14 feet above standard low water from July 30 until field operations were suspended on account of severe weather on December 6.

During the second half of the year it was above that stage from the middle of February until the end of June, with the exception of the twenty-six days ending April 22.

Considering the cost per unit of measure, the low stages prevailing during the first half of the year were more favorable for the construction of hurdles, but the value of the hurdles should be based upon the results they secured by inducing deposits within the areas which are to be reclaimed by them, and considered in this connection the hurdles built during the high stages are the most economical.

Flood stages.—The year opened and closed with the river in flood, and another remarkable one occurred about the middle of February, when the ice gorges above were broken up by a rise of 20.5 feet between the 13th and 18th. Of this rise 9.8 feet occurred within the twenty-four hours ending at 1 o'clock p. m. on the 16th.

The flood, which had about reached its height at the beginning of the year, caused considerable damage to the hurdles at Horsetail and Twin Hollows, west side. Only 900 feet of primary hurdle had been constructed at Jim Smith's, and this sustained only slight damage. At Twin Hollows, east side, and Beard's Island, where bank protection was in progress, the only injuries sustained were to mattresses which were under process of fabrication. The completion of mattresses was delayed at both localities; a part of the one at Twin Hollows was driven ashore by the accumulation of drift-wood, while the one at Beard's Island was finally lost by the parting of its mooring lines.

Upon the decline of the flood heavy deposits were made in areas inclosed by hurdles at each of the localities.

At Jim Smith's the channel, which had been divided into several branches, each of which had small depth, was concentrated into a single stream deep enough for the largest vessels that were engaged in navigating the river.

The height to which the river attained in February—22 feet above standard low water—would scarcely entitle that rise to be classed among floods, but the ice borne by its swift currents from the gorges which had broken in the Missouri River damaged river works and crafts more than the drift-wood which accompanied the other floods, and that fact places it in the rank of floods, when considered as a destructive agent. The contraction works at Horsetail, Twin Hollows, and Jim Smith's were seriously injured by the ice driven by the excessive currents of this flood, the extent of which has not been definitely ascertained, on account of the continuous high water

since that date. The facts, as far as known, are stated in the reports of resident engineers stationed at these localities.

At Twin Hollows, west side, the cribs in secondary lines Nos. 4 and 5 were moved out of place by the ice, which was formed during the winter in the inclosed spaces above them, and which went out in large fields when the flood was about its extreme height. Of the hurdles reported lost at the different works a portion of them are probably serviceable at lower elevations, having been mashed down by the weight of ice.

Large deposits were secured in the inclosed spaces.

The flood of June reached its summit on the 25th of the month, and its deposits within the areas inclosed by hurdles were made too late to be shown on the plates which accompany these reports.

An examination made from the pilot-house discovered that very satisfactory changes had been induced by the works during the first ten days of the flood's decline, which were shown in the large deposits made within inclosures, and in the concentration of the navigable channel into a single stream having abundant width and depth, and the changes in direction are by such easy curves that it can be run by the largest towboats upon the river, with fleets of barges, under full head of steam.

Weather.—During the first half of the year the weather was favorable for field operations up to December 6, when a severe storm set in of wind, accompanied by rain at first, which was soon replaced by snow. The temperature fell rapidly, reaching 19 degrees below zero within twelve hours after it began. This storm set in during the afternoon, and on the following morning the river was so full of sharp, thin ice that boats, barges, and other vessels appertaining to the plant could not be safely left in exposed situations, and in consequence they were harbored, some temporarily at the localities at which they happened to be, and others were sent to the winter harbor, which had been selected at Twin Hollows. The high stage of the river prevented the formation of gorges at once, and an opportunity was thus afforded to transfer all of the plant to the winter harbor within a few days, except two pile-drivers, which were left at Beard's Island and Jim Smith's, respectively.

High winds prevailed during the greater part of the working season of the second half year, which retarded the progress of constructing hurdles.

Rafts of piles were delayed en route, which at times caused suspension of work for lack of material. On some days the pile-drivers could not be operated with safety in the high waves which occurred more frequently than usual on account of high upstream winds that met the unsheltered current of a high river. Of the whole time from March 1 to June 30 not less than one-half was unfavorable for making the movements of vessels and pile-rafts needed in the prosecution of the work.

CARE OF EMPLOYÉS.

Quarters and subsistence.—Persons employed upon the works away from the city were furnished with quarters and subsistence by the United States, as in the preceding year, with satisfactory results.

Sanitary measures.—After the subsidence of the summer flood, malarial diseases became so prevalent that the working parties could not be kept full, although the number of applicants was far in excess of the ordinary demand, and men were received upon the works daily. A few days' exposure to the influence of the malaria of the bottoms seemed sufficient to prostrate the stoutest men with intermittent fevers or with chills. To counteract these malarial influences in part at least, fires were lighted in the quarters an hour before breakfast every morning and after dark, and a wine-glass of a mixture of cinchona bark and whisky was given to each employé who was subsisted by the United States, during the sickly season.

COMMUNICATIONS.

Telephone.—The supply depot and the offices of resident engineers located upon the west bank of the river have been in direct communication with the Saint Louis office and with each other by the telephone line which at the beginning of the year was in operation from the main office to the mouth of the Meramec River, with intermediate stations at Supply Depot, Horsetail Bar, and Twin Hollows.

An intermediate station was established at White House, opposite Beard's Island, and the line was extended to Bushberg, opposite Foster's Island, during the year.

Some annoyance was experienced by interruptions in the working of this long line, which, in a majority of cases, could be traced to electrical disturbances, which prevented the ringing of the call-bells, and this was partially overcome by placing a listener at each instrument at stated hours.

Other means.—The available means of communication other than by telephone were: By mail from Jefferson Barracks and Kimswick, Mo., and Meramec Point, Ills.; by telegraph from Jefferson Barracks and Kimswick, and by the steamers and small boats of the plant, as in the preceding year.

STABILITY OF THE WORKS.

Bank protection.—The works which have protection of banks for their object have been severely tested at the several localities where they have been applied, and have not yet failed to afford efficient protection and to arrest the most obstinate and active erosion at once. Difficulties have been encountered in placing mattresses for low-water protection in deep, swift water, flowing in whirls or crossing the line of works obliquely, which have in some cases been so excessive that losses have occurred during the process. The protection has been perfect, however, from the instant the mattress was placed, in every case.

Contraction works.—Works which have for their object the reclamation of land from the river are necessarily exposed to the action of the current, at times loaded with ice and drift-wood through longer periods, and have sustained more or less damage during floods and in breaking of ice gorges formed during the winter.

They have frequently, however, accomplished the object for which they were built, by inducing deposits after they had been torn out of place, broken down, or turned over, showing that they were efficient, though not strong enough to resist the pressure to which they may be subjected by accumulations of ice and drift-wood.

II.—*IMPROVING THE CHANNEL OF THE MISSISSIPPI RIVER OPPOSITE THE CITY OF SAINT LOUIS, MISSOURI.*

The works under the above heading have for their object, first, the closing of Cahokia chute; second, protecting the west bank of Arsenal Island.

Mr. C. D. Lamb, resident engineer, was charged with the immediate supervision of these works during the last half of the year.

CAHOKIA CHUTE.

Cahokia Dam.—The dam constructed across this chute during the fiscal year ending June 30, 1879, had not only diverted the navigable channel from the east side of Arsenal Island, but had closed the chute at low stages of the river.

The crest of the dam, which was originally five feet above standard low water, was found when work was begun in March of this year at about 2 feet above that plane.

Hurdles constructed.—The work done during the present year had for its object the closing of the chute at medium stages of the river, and the plan adopted included the construction of hurdles across it, above the dam, and two lines have been so constructed.

On account of their exposure to drift-wood these hurdles were built and braced after the forms used in primary lines.

Line No. 1, located 80 feet above the center of the dam and parallel with it, was begun March 17, and completed April 7. The river rose very rapidly about the 23d of April, and reached a stage of 16 feet above standard low water, and the pressure severely tested the strength of the new line. A breach 50 feet wide was made about 400 feet from the Illinois shore, and the piling upon a section of the same length adjoining the island was pressed out of vertical position.

Prompt action restored the efficiency of the line before further damage was done. This line is 1,800 feet long; the average depth of hurdle is 13 feet, giving an area of 23,400 square feet. The foundation mattress extends over the entire length, is about 62 feet wide, with an area of 112,200 square feet.

Line No. 2, located 1,100 feet above No. 1 at the island, and 2,100 feet above it at the other end, was begun April 2, and continued until the 17th of May, when the submergence of the piles caused a suspension. After this continued high water prevented permanent resumption.

An attempt to continue work was checked by another rise June 5.

The length of the line is 2,500 feet, of which 1,300 feet are completed, and the remaining 1,200 feet lacks only the wattling for completion.

Results.—The time that elapsed after the hurdles became efficient in inducing deposits was too short to secure large results during the fiscal year. Within that period there were only a few days upon which deposits would probably be secured, and these were during the last week of the year, after the flood began to subside, while the river, heavily laden with sediment, was falling at the rate of one to one and one-half feet per day.

Soundings taken July 2, 1883, show that during the preceding month a deposit to the depth of 7 feet upon the average was made over the whole area comprised in the part of the chute which lies above hurdle No. 1.

Reference is made to Plate I for locations, and to the report of Mr. C. D. Lamb submitted herewith, for further details.

The expenditures aggregated $40,873.88, distributed as shown in the accompanying statement.

STATEMENT OF EXPENDITURES AT CAHOKIA CHUTE FOR THE FISCAL YEAR ENDING JUNE 30, 1883.

Hurdles Nos. 1 and 2:

Labor	$8,915 57	
Piles	6,694 93	
Brush	6,322 71	
Stone	1,672 99	
Rope	97 70	
Wire	75 23	
Iron	21 09	
Nails	2 56	
Spikes	55 65	
Bolts	697 18	
Subsistence	4,265 56	
		$28,821 17
Steamer Humphreys	421 26	
Steamer Gillmore	130 00	
Launch Hornet	436 94	
Pile-drivers	2,412 13	
Barges	20 01	
Barge flats	959 40	
Quarter-boats	296 66	
Quarters	1,061 72	
Small boats	1,022 00	
Tools and appliances	1,179 92	
		7,940 04

Engineering and contingencies:

Engineering	1,025 13	
General expense	2,108 09	
Telephone	575 16	
Office furniture	23 72	
Instruments	55 53	
Contingencies	325 04	
		4,112 67
		40,873 88

ARSENAL ISLAND.

A full account of the operations at this locality may be found in Part I, and in the accompanying report of Mr. C. D. Lamb.

The expenditures which were charged to the special appropriation for improving the channel of the Mississippi River opposite Saint Louis, Mo., aggregated $6,194.07, distributed as shown in the accompanying statement.

STATEMENT OF EXPENDITURES AT ARSENAL ISLAND FOR THE FISCAL YEAR ENDING JUNE 30, 1883.

Low-water protection:

Labor	$487 96	
Piles	147 74	
Brush	760 95	
Stone	229 14	
Rope	61 36	
Wire	26 75	
Spikes	15 04	
Steamer Humphreys	28 10	
Pile-drivers	46 08	
Small boats	44 88	
Tools and appliances	88 86	
		$1,936 86

Medium stage protection:		
Labor	$1,007 55	
Stone	2,860 07	
		$3,867 62
Engineering and contingencies:		
Engineering	2 85	
General expense	220 94	
Telephone	33 44	
Office furniture	92	
Instruments	2 76	
Contingencies	128 68	
		389 59
		6,194 07

2.

ARSENAL ISLAND.

REPORT OF MR. C. D. LAMB, ASSISTANT ENGINEER.

ARSENAL ISLAND, *July* 1, 1883.

MAJOR: I have the honor to submit the following report of operations at Arsenal Island during the fiscal year ending June 30, 1883:

The portion of this report referring to the work done during the fall of 1882 is the substance of the report made by Mr. A. F. Freis, resident engineer, who was in local charge at that time.

* * * * * * *

The work done during the past year is located, as shown on the accompanying tracing, Plate I, by numbered stations 100 feet apart extending down-stream from the 0 station, which is at the intersection of the line of Cahokia Dam with the west bank of the island.

Work was resumed at this place August 16, 1882, when the high water which caused the suspension of operations June 30 had subsided to such a stage that work could be carried on to advantage. The guide piles carried away by high water between Stations 54 + 50 and 59 + 10 were replaced, and the line was then extended from Station 63 + 33 to the foot of the high bank at Station 68 + 93. These piles were driven 15 feet apart as heretofore, and at such distances from the shore as would allow the inner edge of the mattress to extend up to the plane of standard low water after being sunk. Meanwhile a small force of men had, since the latter part of July, been engaged in cutting brush upon the island and bringing it to the bank. This force began the construction of a low-water mattress August 25. A section 460 feet long was built and placed to close a gap between Stations 54 + 50 and 59 + 10. The remainder of the mattress built during the half year was used to extend the low-water protection from Station 63 + 33 to the lower end of the high bank at Station 68 + 93.

This mattress, 40 feet wide, was built, as during the previous season, inside the line of guide piles which supported its outer edge while its inner edge rested upon flats. It was composed of two layers of brush crossing each other at right angles and held between grillage poles placed at intervals of 6 feet.

The force was reduced September 14, and employed until the 25th in re-distributing the stone placed between Stations 1 and 36 in the mean stage revetment during the high water of the previous half year.

A supply of stone having been secured, the construction of medium stage revetment was begun at Station 38 + 90. This protection was carried to a height of 16 feet above standard low water to Station 42 + 20. It was raised to 11½ feet above the same plane from Station 42 + 20 to Station 51, but from that point to Station 69 + 68 as well as between Stations 36 + 40 and 38 + 90, it was left at 8 feet above standard low water.

* * * * * * *

The average width of the revetment built during the year was 31.5 feet and covering a surface of 104,540 square feet.

Nothing was done at this place during the last half year. The revetment could not be thoroughly inspected during the spring on account of the prevailing high stage of river, but as far as could be observed the work has not deteriorated since construction, although the bank above the medium stage revetment has been cut back for several feet by the strong currents prevailing during high water.

The hurdle built between Stations 36 and 39 to fill out the bank to the proposed shore-line is slowly accomplishing the desired result. Its outer end, however, has been cut down by ice and drift, and its efficiency would be increased by repairs.

The following statement shows the number of linear and square feet of mattress and revetment built during the year, with the cost of the labor and material used in its construction.

For low-water protection:			
To labor, constructing 1,003 linear feet, 40 feet wide, or 240,120 square feet of mattress	$667 45		
To labor, sinking mattress	60 50		
		$727 95	
To labor, driving piles	101 86		
To pile timber, 65 sticks, 2,661 feet driven	147 74		
		249 60	
To brush, 285 cords		760 95	
To stone, 241¼ cubic yards		229 14	
To rope, 785 pounds		61 36	
To wire, No. 12, 350 pounds		26 75	
To spikes, 375 pounds		15 04	
To equipment, steamer Humphreys	28 10		
To equipment, pile-drivers	46 08		
To equipment, skiffs	44 88		
To equipment, tools and appliances	88 86		
		207 92	
			$2,278 71
To labor, placing 3,328 linear feet, or 104,540 square feet revetment, for mean stage protection		1,007 55	
To stone, 3,010.6 cubic yards, for mean stage protection		2,860 07	
			3,867 62
ENGINEERING AND CONTINGENCIES.			
To engineering		82 85	
To contingencies		128 10	
To general expense		215 05	
To surveys		53	
To telephone		33 44	
To photography		5 89	
To office furniture		92	
To instruments		2 76	
			389 59
			6,535 92

The revetment was uninjured by the high water of June, and while a portion of the west bank of the island was cut away, a deposit 6 feet thick in places was made on its surface, and the high bank at its foot was extended for several hundred feet below the protection.

Very respectfully, your obedient servant,

C. D. LAMB,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

3.

HORSETAIL BAR.

REPORT OF MR. E. D. LIBBY, ASSISTANT ENGINEER.

HORSETAIL BAR, *July* 5, 1883.

SIR: I have the honor to submit the following report of the operations for improvement of the Mississippi River at Horsetail Bar for the fiscal year ending June 30, 1883.

From the beginning of the fiscal year until the close of the season in December, 1882, the work consisted entirely of repairs upon the primary hurdle, and upon secondary hurdles Nos. 18, 23, 27, and 30.

Operations in the field during the second half of the year were confined to the construction of a hurdle across the chute east of Carroll's Island, and near the head of the island. Two divisions are thus naturally made of the year's work.

The detailed account of field-work at the different localities will be given in the following order, viz:

I. Repairs.—1. Primary hurdle; 2. Secondary hurdles Nos. 18, 23, 27, and 30.

II. Construction.—Primary hurdle—Carroll's Island.

I.—REPAIRS.

PRIMARY HURDLE.

Pile-driving.—On account of high water, work on this line could not be resumed until July 22. Upon this date the placing of piles was commenced by pile-driver No. 6; this was reinforced by No. 15 on August 1, and on October 17 by No. 3. With the exception of several interruptions in the work of No. 6, these drivers remained on the line until November 23. The total number of days on which they were thus engaged was 145.

For the most part the piles driven were in a space of about 1,300 feet, beginning at a point 400 feet above secondary hurdle No. 23. (See tracing *a-b* on primary hurdle.) A few piles were driven to repair breaks between secondaries 21 and 22, also between 25 and 27. The remainder were placed at the end of the line, near secondary No. 30. (See tracing *c-d*.)

Wattling.—Wattling upon the primary line occupied a period of twenty-five days, or from September 2 to September 8 on the breaks between secondaries 25 and 27, from October 5 to October 23 between secondary 28 and the end of the line. At the former locality 230 linear feet, average width 14 feet (3,220 square feet), was placed, and at the latter locality 1,330 linear feet, averaging 8 feet in width, or 10,640 square feet.

Placing gates.—Commencing on August 7, was completed on September 19. During this interval repairs of the gates were made from secondary No. 18 to secondary No. 21, while below 21 the work was continuous nearly to secondary hurdle 25. The gates constructed on the Missouri shore were loaded on barges, which were towed to the points where repairs were needed. From the barges they were raised and launched into position by a small force of men. In some cases difficulty was experienced in forcing them down and holding them against the piles as the current set obliquely ontward from the line. Owing to this circumstance it became necessary to fasten the gates to the piles. This was done, chiefly, by spiking—in some instances by lashings leading to the main row. When the water fell sufficiently to permit, they were again spiked to the piles at the water's edge.

The form of these gates and the manner of constructing them has been given in a former report. (See Plate V and text, annual report of assistant engineer A. F. Fries, for fiscal year ending June 30, 1882.)

Mattress.—A foundation mattress 750 feet long and 50 feet wide (37,500 square feet) for repairing breaks between secondaries 22 and 24 was fabricated and sunk on August 7 to September 2; 30 feet of this mattress extended beyond the main row of piles. Another foundation mattress 1,305 feet long and 25 feet wide (31,625 square feet) was fabricated between September 11 and October 5. This was placed from secondary 28 to the end of the line.

SECONDARY HURDLE No. 18.

Pile-driving.—Owing to the high stage of water at the opening of the fiscal year, and the consequent overflow of all the hurdle lines below No. 18, work could be prosecuted upon this line only.

A single pile-driver was engaged until July 8, also on July 12 and 13, in closing a break that existed in the line at a distance of about 300 feet from the Illinois shore (*e-f* of tracing). Longer piles being required than were at hand, it was necessary to tow many that were used at this place from Arsenal Island. On July 4 a break was made in the line about 800 feet from the Illinois shore (*g-h* of tracing). This break was caused by a wreck which struck the hurdle, making a gap 350 feet in length. Repairs at this point were commenced on July 18, and on July 22 the placing of piles to close the break was completed. Two pile-drivers were employed for this work, one of which was received July 18 from Arsenal Island. A single driver continued work on this line until August 1. It was employed in driving piles to replace those that had been forced from the main line and brace row.

Mattress.—One hundred and four linear feet of mattress for break *e-f* was fabricated and sunk on July 14 to July 19. Between July 22 and August 4, a foundation mattress 310 feet in length was constructed and sunk in the gap *g-h*. This completed the foundation mattress for the entire line.

Gates.—Placing of gates closely followed the completion of the mattress and on August 12 all of them were in position. Flats were used for this work instead of barges as on the primary line.

Bracing.—Additional bracing for a distance of 490 feet was placed upon this line.

SECONDARY HURDLE No. 23.

Pile-driving.—From September 4 until the 17th, two pile-drivers were employed in placing the piles necessary for the repairs of this hurdle line; *i-k* and *l-m* of the tracing represents the localities at which the piles were driven.

Wattling and mattress.—Wattling for hurdle 23 was commenced on September 5, and was completed on October 1. The mattress, 150 feet in length, was fabricated and sunk on the 7th and 8th of October.

Bracing required seventeen days, or from October 1 to October 18. On completing this division of the work, repairs on secondary 23 were done.

SECONDARY HURDLE No. 27.

Pile-driving.—Two pile-drivers were engaged in driving piles on No. 27 from September 17 until October 11. After the latter date one driver was used in placing braces at other points and the second driver was retained on this line until its completion.

Mattress and wattling.—From October 11 until November 20, a force was employed in placing the wattling for line 27; this time includes, however, a period of eight days on which the foundation mattress, 382 feet in length, was fabricated and sunk.

Curtains to be placed between the bar and shore were constructed on October 4 to 11. In this time 375 linear feet, average height 30 feet, were made.

These curtains, having been constructed on the bar above the line, were floated down to the hurdle and were then raised into position by a pile-driver.

In some cases it was found impossible, on account of obstructions consisting of portions of old work, to force the wattling to the bottom. To close the space between the bottom of the wattling and the bed of the river narrow curtains were employed. These were placed on November 20 to 23. This work put the line in complete repair.

SECONDARY HURDLE No. 30.

Pile-driving on secondary hurdle No. 30 was begun on November 23, and continued until the close of the season, at which time all the piles necessary for closing the line had been driven. On the tracing *n–o* represents this work at the east end of the line and *p–q* at the west end.

Mattress and wattling.—One hundred and twenty linear feet of foundation mattress was fabricated and sunk, and 1,760 linear feet of wattling was placed.

For the completion of this hurdle 395 linear feet of wattling must be placed, and 250 linear feet of foundation mattress must be fabricated and sunk.

Active work was suspended on December 6, and a portion of the force was discharged. On December 14 the remaining men were paid and discharged, their services between the 6th and 14th having been employed in collecting and securing the property for winter. The pile-drivers and other floating engineer property, except skiffs and yawls, were placed in winter harbor at Twin Hollows.

No work was done on the west side during the fiscal year. The condition of the hurdles at that location upon the close of the season was good, excepting the primary line. This, between secondary hurdles Nos. 2 and 8, received some injury during the high water.

An examination in December of the work upon the east side showed that the construction work placed in the primary line between secondaries 27 and 29 during the season of 1881 has been badly injured by running ice.

From the nature of the work, progress upon the repairs of the several hurdles has been somewhat slow. Before new work could be placed in the breaks drift was to be pulled, and oftentimes broken and leaning piles as well. In many cases it was impossible to remove all obstructions, and thus additional hindrances were to be overcome in placing the new work.

In a locality so thickly studded by sand-bars as this, the moving of plant and material from one point to another forms a large item in the work.

Nearly all the material expended in repairing the secondary hurdles had to be towed by small boats from a distance.

From September 4 to November 4, about half an hour was lost each day in crossing the river for dinner. At the latter date arrangements were made to send this meal to the workmen.

During the second half of the fiscal year it has been impossible to obtain accurate information regarding the condition of these works, owing to the fact that the river has remained at an unusually high stage. From what could be learned when the water was at its lowest it is evident that the primary line was considerably injured by the floating ice, and secondaries 27 and 30 as well, although in a less degree than the primary.

At the close of the fiscal year the river was running high over all the works at this point.

The soundings given on the tracing were taken on June 25, 26, and 27.

It was impracticable to determine new shore lines, as the river covered a large portion of the land east of the bluff. Carroll's Island was also almost entirely submerged.

The tracing shows the condition of this portion of the year's work as it was on December 31, 1882.

II.—CONSTRUCTION.

PRIMARY HURDLE—CARROLL'S ISLAND.

In accordance with instructions contained in your letter of March 14, 1883, a hurdle was commenced, on the opening of the working season in 1883, across the chute east of Carroll's Island near the head of the island, and operations were continued at this locality until the river reached such a high stage as to prevent further work of construction.

A small force was put in the field on March 20, but the equipment of quarters, the transportation of engineer property from the shore quarters on the west side, and the preliminary work incidental to the location of a new work prevented the commencement of active operations on the hurdle before March 26.

As represented on the tracing by A, B, this line extends from the head of Carroll's Island obliquely toward the Illinois shore, which it meets at a point about 1,500 feet below Dike 5. The length of the line A–B is 2,450 feet. The form of hurdle adopted consists of three rows of piles—drift, hurdle, and brace rows—foundation mattress and wattling of brush, diagonal bracing from foot of brace piles to hurdle row and from foot of hurdle piles to drift row, longitudinal stringers the entire length of drift and hurdle rows, and cross stringers from drift to brace piles. With the exception of the diagonal bracing between hurdle and drift piles the form of construction is similar to that heretofore employed.

Pile-driving was commenced in the last week of March by drivers Nos. 11, 16, and 17. Number 11 was transferred to Chesley Island on April 19; the others continued operations till the work closed for the "June rise." The small channel west of a bar, about 650 feet wide at the 20-foot stage of the river, was first closed, after which the drivers were placed on the eastern end of the line. They succeeded in driving piles to the Illinois shore, and also over the bar, before the water became too high for further work.

Mattress construction kept pace with the pile-driving, and at the close of operations the mattress had been constructed and sunk for the entire line, with the exception of about 100 feet near the Illinois shore. The foundation mattress has an average width of 46 feet, and extends from 6 to 8 feet beyond the drift row up-stream.

The wattling is continuous for a distance of 1,625 feet from the island, and is carried to the stage of the river 16 feet above standard low water. Eight hundred and twenty-five linear feet of wattling is needed to complete this part of the work on the line. Bracing and stringing were carried on at somewhat irregular intervals as small forces could be spared from the mattress and wattling gangs. Cross stringers are required for a distance of 450 feet in order to complete 850 feet of the line. Braces were hung and not bolted for some distance beyond this point; 1,875 linear feet of stringers were placed on the drift row.

The rise in the river on the last of May caused a cutting away of the island at and below the intersection of the hurdle line with the shore. To aid in protecting the island and in securing a better shore connection for the hurdle a mattress, similar in construction to a protection mattress, was commenced on June 11, at a point about 200 feet above the head of the island. This was continued until the high and rapidly rising river terminated the work of construction for the year. The mattress was 145 feet long and 51 feet wide.

The long-continued and extremely high water has interfered very much with the prosecution of the work at this locality. On May 22 the force was reduced to watchmen only. Instructions were received on June 4 to resume operations. This was done, but a heavy rise of the river soon set in, and the force was again discharged on June 18. The fleet was moved to more secure quarters on the west shore about half a mile above Jefferson Barracks.

Violent winds on many days have made the work slow and difficult, and on several it was necessary to suspend operations entirely.

Serious delays have been caused by the failure of the contractor to deliver piles in sufficient numbers and of suitable lengths. Delays from this source have affected all portions of the work.

Appended to and forming a part of this report are tables showing the progress of work during the year and giving the amount of material expended thereon.

I have been ably assisted in the prosecution of the work by Messrs. C. P. Mitchell and S. B. Cady.

Very respectfully, your obedient servant,

E. D. LIBBY,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

Tabular statement showing the amount of work accomplished during first half of fiscal year 1883.

Location.	Piles for bracing.	Piles driven.	Mattress placed.	Curtains placed.	Wattling placed.	Gates placed.	Totals.	
	No.	*No.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*	*Sq. ft.*
Primary line	286	271	2,055	.....	1,560	2,512	5,772	59,196
Secondary line, No. 18	120	140	414	.....	.....	556	1,240	10,008
Secondary line, No. 23	79	150	150	.....	1,110	.....	1,110	16,650
Secondary line, No. 27	159	292	382	765	1,270	.....	1,650	36,200
Secondary line, No. 30	193	271	120	.....	1,760	.....	1,760	28,160
Total primary line	286	271	2,055	.....	1,560	2,512	5,772	59,196
Total secondary line	551	853	1,066	765	4,140	556	5,760	90,418
Totals	837	1,124	3,121	765	5,700	3,068	11,532	149,614

Tabular statement showing the amount of work accomplished during second half of fiscal year 1883.

Description.	March.	April.	May.	June.	Total.		Total.
					Linear feet.	Square feet.	
Piles driven	182	529	86	14	.....	.....	811
Diagonal braces	.....	90	147	.....	.....	.....	237
Longitudinal stringers	.....	12	39	.....	.....	.....	51
Cross stringers	.....	49	.....	.....	.....	.....	49
Mattress	.....	1,745	540	.....	2,285	104,390	.....
Wattling	.....	832	755	.....	1,587	17,710	.....

4.

TWIN HOLLOWS, WEST BANK.

REPORT OF MR. WILLIAM S. MITCHELL, ASSISTANT ENGINEER.

TWIN HOLLOWS, WEST BANK, *July 7*, 1883.

MAJOR: I have the honor to submit the following report of operations for the improvement of the Mississippi River at Twin Hollows, west bank, for the fiscal year ending June 30, 1883.

On the accompanying tracing is shown in black the work which was standing when the high water which prevailed at the beginning of the year had passed, and the condition of these works was as follows:

PRIMARY HURDLE.

The crib which had been sunk next the Missouri shore was in good condition and only required wattling to thoroughly complete it. This, however, could not be done at once on account of the drift which had accumulated in front of it. Between this crib and the upper end of the piling (Station 6+20) there existed a gap with deep water, to fill which a crib similar to the first was in process of construction. For 150 feet (Station 6+20 to Station 7+70) the hurdle had been completely broken down, and from that point to secondary hurdle No. 1 the wattling and bracing were both in need of repair.

From secondary hurdle No. 1 to a point 500 feet below No. 2 (Station 55) and two small pieces of the line 400 feet and 500 feet long, and lying, respectively, between lines Nos. 2 and 3, and immediately above No. 4, the hurdle was complete and in good condition.

The piling which had been extended 400 feet below No. 4 was also unharmed, although it was in several places so overlaid with drift as to render further work at those points impossible.

The mattress which had been sunk over the piling was intact, although, of course, it could not be seen. Had scour occurred under any portion of it, the piling, or rather a gap in the piling, would have shown it.

SECONDARY HURDLES.

All that remained in No. 1 was about 160 feet of braced piling next to the primary line. The rest had been carried out by drift. There was in process of construction a crib 203 feet × 30 feet × 30 feet, for the west end of this hurdle.

In line No. 2 there remained next to the primary hurdle 550 feet of piling unwattled, and in front of which there was an immense accumulation of drift.

In hurdles Nos. 3 and 4 no damage was sustained. In each instance the hurdle was complete and intact as far as it had been extended.

The high water which prevailed during June continued with a steady rise until July 5, when a maximum height (26.35 feet above standard low water) was reached. It then began falling and continued to recede until 4.4 feet was reached October 12, when it again rose slowly and stood during the remainder of the season at about 7 feet.

The weather and stage of river during the fall season was very favorable to the prosecution of the works, the only drawback being the prevalence of malarial fevers among the men, due to the previous long-continued high water. Such preventative medicines as were administered and the precaution of keeping the quarters dry and warm in the mornings and evenings had a very beneficial effect.

Although one hundred men were employed during July in the construction of the cribs already referred to, active operations were not resumed until August, during which month the force was gradually increased, reaching three hundred men September 1, when it was reduced on account of the transfer of some of the quarter boats to other works to about two hundred men, at which number it remained until November. From that time until the close of the season the force averaged only one hundred and forty men. This was in large measure due to migration of the laborers, large numbers of whom went south on the approach of winter.

The effective working force at the West Bank was still further reduced during the last six weeks of the season by a small force of men who were engaged in making repairs to and extending the hurdle at Pulltight.

The work done during the past year is shown on the tracing in red, and is also given in detail in the accompanying tables.

The zero or initial points of the hurdles, referred to in these tables, are assumed as follows:

For the primary hurdle, a point on the line of the hurdle 3,000 feet above its point of junction with secondary hurdle No. 1.

For the secondary hurdles, their points of junction with the primary line. Consequently, for lines Nos. 1, 2, 3, 4, and 5, the initial points correspond to the stations referred to in the tables as stations 30, 50, 70, 90, and 110, respectively.

There are also given tables showing the total amounts of work done in the various classes of construction and the amounts of material expended.

5455—E 83——77

Hurdle.	Class of construction.	Complete July 1, 1882.		Complete July 1, 1883.		Constructed during fiscal year 1882-1883.
		From station—	To station—	From station—	To station—	
						Linear feet.
Primary hurdle (Length, 12,130 feet).	Piling	7+75	94+20	6+20	94+20	2,005
				104	122+50	
	Double width mattress	7+75	63+60	6+20	80	4,075
		70	77	81+70	94+20	
		84+60	90+60	99+20	122+50	
	Wattling	7+75	20+50	Front of crib.	Feet, 375	
		22	55+50	6+20	55	
		59+50	63+60	59	63+20	3,880
		84+60	90+60	67+50	77	
				84+80	95	
				104	122+50	
	Crib-work	Missouri shore.	250 feet east.	250 feet east.	6+20	250
	Willow plantation			94+20	99+20	500
Secondary hurdle No. 1 (Length, 1,000 feet).	Piling	0	1+60	0	7+30	570
	Mattress	0	1+60	0	7+30	570
	Wattling				1+60	10
	Crib-work				7+30	10
Secondary hurdle No. 2 (Length, 1,120 feet).	Piling	0	5+50	0	8+20	270
	Mattress	0	5+50	0	8+20	270
	Wattling				5+50	570
	Crib-work				8+20	300
Secondary hurdle No. 3 (Length, 1,260 feet).	Piling	0	7+60	0	11+90	1,020
	Mattress	0	7+60	0	7+40 (590 feet) 11+90	572
	Wattling	0	7+60	0	7+00 (443 feet mat.) 10+60	605
	Crib-work			11+50	12+60	175
				11+90	12+55	
				11+50	12+60	
Secondary hurdle No. 4 (Length, 1,490 feet).	Piling	0	8+50	0	11+50	300
	Mattress	0	8+50	0	11+50	300
	Wattling	0	8+50	0	11+50	
				12+30	14+90	Placed, 410, Unplaced, 130, 840
	Crib-work			12+30	14+90	Placed, 404
				12+30	13+80	Unplaced, 190
Secondary hurdle No. 5 (Length, 1,600 feet).	Piling			0	13+40	1,340
	Mattress			0	13+40	1,340
	Wattling			0	13+40	
				14+20	15+70	1,640
				14+35	15+85	
	Crib-work			14+20	15+70	300
				14+35	15+85	
	Protection mattress			Missouri shore.	(451) 6+20	1,476
				6+20	16+45	

Table showing total amount of work done during fiscal year 1882–'83.

Description.	Primary hurdle.	Secondary hurdle.	Total.
	Linear feet.	*Linear feet.*	*Linear feet.*
Piling	2,005	3,500	5,505
Mattress	4,075 double width	3,353 single	11,503 single.
Wattling	3,860 × 13	4,495 × 13	8,355 × 13
Crib-work	250 large crib	506 shore cribs, 1,133 large cribs.	1,889
Protection mattresses	451 feet on wire and	1,025 on brush stringers	1,476

Table showing quantities of material expended during fiscal year 1882–'83.

Material.	Primary hurdle.		Secondary hurdles.		Protection mattress.	Total expended.
	Hurdle.	Crib.	Hurdles.	Cribs.		
Bolts:						
Drift.....number..	653	.....	313	908	.....	1,874
Eye.....do....	112	150	.....	474	.....	736
Ring.....do....	.....	60	108	90	.....	258
Screw.....do....	196	202	411	1,030	15	1,854
Brush.....cords..	1,423.22	.....	1,224.58	73	993.17	3,713.97
Clevises.....number..	234	82	115	406	.....	837
Lumber, pine.....feet, B. M..	.....	.....	.....	64,000	.....	64,000
Nails:						
6d.....pounds..	.....	.....	.....	.....	.....	*65
10d.....do....	.....	.....	150	30	.....	180
20d.....do....	100	.....	724	301	300	1,425
Pile timber.....feet..	39,950	3,914	45,324	28,309	1,857	119,354
Rope:						
Hide.....pounds..	149	.....	70	.....	.....	219
Sisal, ½-inch.....do....	31	.....	32	.....	.....	63
Sisal, ¼-inch.....do....	152	56	26	322	50	606
Sisal, ½-inch.....do....	580	108	350	744	72	1,914
Spikes:						
6-inch.....pounds..	750	150	680	784	900	3,264
8-inch.....do....	700	.....	1,035	692	400	2,827
10-inch.....do....	.....	.....	243	1,924	.....	2,167
Stone.....cubic yards..	1,537.57	499.45	314.75	842.98	453.86	3,648.61
Washers.....number..	125	300	110	1,336	.....	1,871
Wire:						
No. 9.....pounds..	.....	.....	475	250	3,545	4,270
No. 12.....do....	1,300	.....	1,200	100	.....	2,600
No. 14.....do....	2,326	.....	3,593	.....	700	6,619

* On quarters.

PRIMARY HURDLE.

The crib which was in process of construction for this hurdle was completed during July. It was 250 feet long, but for convenience in sinking it was cut in two. The sections were placed July 28 and August 2, on the line of the prolongation of the crib, which was sunk in June, and with it formed a barrier across the gap which had existed at the head of the works since their inception. The outer end of the east section of crib-work protruded beyond the line of the hurdle about 25 feet.

Immediately after the sinking the piles were redriven from the east end of the crib-work down-stream 150 feet to the main line and a mattress was sunk over them. They were then braced and wattled, and the whole line between this point and the angle (1,850 feet) was repaired. A few of the piles were straightened and some required redriving. About one-third of the braces were reset, and fully one-half of the line was rewattled.

On August 7 a small break was discovered in the line about 100 feet below secondary hurdle No. 3. Being in the pocket or angle between the primary line and the bar on the outside, a considerable stream of water was forced rapidly through it and soon widened the breach to 300 feet, scouring the bottom in the immediate vicinity from a depth of 4 feet to a depth of 12 feet.

The piles were immediately redriven, a single-width mattress was sunk over them, and curtains of brush woven on wire were dropped in front of them in the place of wattling, when the piles were at once carried out. The line was again restored, and an outside line was driven 20 feet in front of it and curving back to meet the main line on either side of the gap. A double-width mattress was made and sunk and both

lines of piles were wattled, the wattling in the original line being carried on each side to the 20-foot contour on the bars. Twice since then evidences of scour have been discovered under the mattress at the shore ends. Each time the mattress was cut to fit accurately to the bottom and was heavily weighted with stone, and the danger was removed.

Below hurdle No. 3, and above No. 4, two sections of double-width mattress were built in place on the bar. These sections are respectively 260 feet and 300 feet in length, and are separated by a space of 200 feet, in which drift had collected so heavily among the piles as to render its removal impossible.

Below hurdle No. 4 two other sections of this mattress were built on the bar. The first was 450 feet long, and extended from No. 4 to the end of the piling driven previous to July 1, which piling was also wattled. The other section was about 500 feet long, and extended that distance up-stream from the lower water edge of the bar. No piling has as yet been driven over this portion of the line.

In the 500-foot space between these two mattresses the bar is about 20 feet above extreme low water, and here it was decided to make a plantation of willows.

For this purpose six trenches were dug 2 feet apart on the line of the hurdle. They were each 1½ feet deep, and 500 feet long, and in them freshly cut willow shoots were buried, leaving exposed only the leafy tops. The plantation was made in the latter part of September, and although the bar, which was composed of pure sand, was wet at that time, it soon dried out under the hot sun, and the willows, for want of a moist soil, died.

From the lower edge of this bar a complete section of the primary line was extended to a point 1,250 feet below secondary hurdle No. 5 (Station 122 + 50). This point was reached during the latter part of November. An attempt was then made to push the line down-stream another 200 feet, in order that the contracted channel might induce a more active scour in the bar below. It was found impracticable, however, to do this, as the rapid current which crossed the line at this point forced out the piles before a mattress could be constructed and sunk over them. A short section of mattress was placed, however, without piles across the end of the completed hurdle to prevent scour from the lower side, and the line was left for the winter.

At the close of the season the primary line was complete so far as it had been begun with the exception of 1,000 feet from the upper end of the willow plantation to the lower edge of the bar.

SECONDARY HURDLES.

No. 1.—The crib which was constructed for this hurdle was completed and sunk at the west end of the line July 21, and the hurdle itself was entirely completed from this crib to the portion of the line left standing by the high water, a distance of 570 feet.

No. 2.—On August 19, a crib 206 feet long was placed at the west end of the hurdle. While swinging into position the east end grounded on a bar which had formed during the time of its construction and remained in that position, about 20 feet up-stream from the line of the hurdle. The small gap thus formed between the crib and the hurdle was closed by driving piles across it. The 270 feet of the line between the east end of the crib and the portion of the line already in was entirely completed.

No. 3.—In this hurdle 410 feet was built at the west end of the line and 50 feet additional was wattled. Owing to a deposit of sand extending to the bank, piles were driven to the water's edge on the Missouri shore and the construction of a crib was avoided.

No. 4.—For the shore end of this hurdle a crib 150 feet long was constructed and sunk September 29. In addition the completed line was extended 300 feet farther west. A gap 80 feet wide was thus left between the crib and the hurdle through which material was taken to the works above this line.

No. 5.—A crib 144 feet long was constructed and sunk October 27 at the west end of this line, and 1,340 feet of the hurdle extending from the primary line towards the Missouri shore was completed. A gap similar to that in No. 4, and for the same reasons, was left in this hurdle between the completed section and the crib.

At the time the cribs for these last two hurdles were sunk there was practically no current crossing the lines. This permitted wattling the fronts of these structures previous to sinking. The fronts of all the others were wattled after they were placed.

In addition to the large cribs, there were built in place on the shore short crib structures averaging 85 feet in length at the extreme west ends of secondary hurdles Nos. 1, 2, 3, and 4, and extending these hurdles from the water's edge to the 20-foot contour on the bank. The fronts of all these structures were wattled.

At the close of the season the first three secondary hurdles were complete, and in the other two it only remained to close the gaps mentioned and to construct a shore crib for No. 5.

In the construction of the hurdles the ordinary methods of work, with the modifications which had proved successful during the previous year, were used, and no

especial difficulty was encountered. In each case the piling was pushed as far towards the shore as the depths of sand on the bottom would warrant, in order that the building of cribs might be reduced to a minimum, this form of construction having proved much slower and more expensive than that of the ordinary hurdle.

PROTECTION MATTRESS.

When the water had reached a low stage it was seen that a narrow strip of sand extended on the outside of the primary line from the angle above hurdle No. 1 to No. 3. This beach widened gradually to 125 feet at its lower end. From the water it ascended with a tolerably regular slope to the piling, where at a number of points it reached the 20-foot level. The slope towards the channel was much more gentle, forming in front of the training-wall a wide shoal.

During the low water, between September 1 and October 15, the river, in adjusting itself to the new regimen effected by the works between the River des Peres and Jim Smith's Landing, attempted to straighten out and form a new channel midway between the primary hurdle and the Illinois shore. In so doing this shoal was gradually deepened, and the sand beach was eaten away to the piles for a distance of 1,000 feet, to a point one-third way between secondary hurdles Nos. 1 and 2, an erosion which continued slowly during the remainder of the season. In order to protect the piles from this scour, it was decided to treat the primary line as a new bank of the river and to revet it with a broad low-water mattress.

A ways-barge and quarter-boat for the accommodation of laborers were placed in position at the head of the works October 22, and the construction of a mattress was begun. The first section of mattress was 316 feet long by 104 feet wide and extended from the shore to the outer end of the crib-work. It was woven on pairs of wires (No. 9) placed 6 feet apart. The brush was placed between the wires of each pair and the wires were then tightened by hand and twisted with a full turn to fasten them.

For 200 feet from shore it was sunk without difficulty, but from that point it went down so rapidly with the current that stone could not be distributed over it fast or evenly enough to prevent its bagging and folding up.

Another mattress, 135 by 104 feet, was constructed in the same manner and sunk over this outer portion to repair the damage done to the first. This mattress also proved so flexible and difficult to handle that it was decided to return to the ordinary method of weaving the mattress on stringers made of poles. The barges were then placed in position around the end of the cribs and a continuous mattress, begun November 11, was constructed and sunk, reaching a point 1,025 feet below the upper end of the primary line.

At first the progress made was very slow, but as the men became accustomed to the work the rate rapidly increased. Within a fortnight it rose from 25 feet to 70 feet per day, and on one day in December 102 feet were constructed. At first a row of guide piles for this mattress was driven 10 feet outside of the hurdle, the piles being spaced 20 feet apart. This was afterwards discontinued, the hurdle itself serving the purpose.

On December 6 heavy ice began running in the river and an end was put to the season's work. The barges, quarter-boats, pile drivers, &c., were placed in winter harbor behind the primary hurdle and the bar[illegible]l below hurdle No. 4.

Table showing amounts of work done from July 1 to December 6, 1882.

Description.	Primary hurdle.	Secondary hurdle.	Total.
	Linear feet.	*Linear feet.*	*Linear feet.*
Piling	2,005.	2,910.	4,915.
Mattress	4,075 double width.	2,910 single width.	11,060 single.
Wattling	3,860 × 13.	3,960 × 13.	7,820 × 13.
		341 shore cribs.	
Crib-work	250 large crib.	703 large cribs.	1,294.
Protection mattress	451 on wire and 1,025 on stringers.	.....	1,476 × 104.

Work was not resumed until March 1, when a pile-driver was placed at work dredging for piles in sunken rafts, and a small force of men began the construction of cribs for secondary hurdles Nos. 4 and 5, to repair the damage done by the ice and flood of February.

The ice which broke up and passed down the river with this rise was exceptionally heavy, and did considerable damage to the hurdles. The exact extent of the damage can hardly be told, as it has been impossible to get a good view of the hurdles since that time.

From March until the middle of May the water has never been more than a few feet below the 20-foot level, thus exposing only the tops of the hurdles; and from that

time until June 25 it rose steadily, reaching, on the latter date, an elevation 28 feet above standard low water. On June 30 it had again retired to 26 feet.

The condition of the works, however, as determined by observation and sounding, was as follows:

In the primary hurdle, from the middle of the crib-work at the head of the line to Station 7, the hurdle was submerged and probably much broken. It is not gone, however, as a distinct break in the water shows that the obstruction is still in place. In the next 1,400 feet of the line a number of small gaps appeared, none of which were at all serious. From this point to Station 23 the hurdle has been bent over by the ice, very few piles showing above the surface of the water. From secondary hurdle No. 1 to a point 450 feet below hurdle No. 5 (Station 114+50) the line is intact. Below this two breaks occur, one 150 feet wide, extending to Station 116, and the other from Station 117+25 to the end of the line. From the latter the hurdle was entirely gone.

In secondary hurdle No. 1 a small gap, about 75 feet in width, appeared at the east end of the crib.

From hurdle No. 2, the shore crib had been carried away. This was also the case in No. 3, and in the latter line an additional gap appeared between Stations 7+40 and 9+30.

The cribs which were sunk in lines Nos. 4 and 5 during the low water in the fall, having received no deposit over their floors, were not able to withstand the weight of ice which the rise in the river brought against their tops, and they were rolled over and pushed down stream several hundred feet in each instance and in to the shore.

The cribs which were begun, to replace those destroyed were completed during March, their fronts were wattled and they were sunk in place, one April 2, in secondary hurdle No. 4, and the other April 7, in secondary hurdle No. 5. A second crib for hurdle No. 4 to stand in the gap at the east end of the crib already placed was begun and completed in April, and an attempt was made to sink it May 3, when, after getting it into position and nearly to the bottom, several anchor lines broke and let one end of the crib swing through the gap in which it was to stand. After a fortnight's labor the crib was raised and strapped up to the barges and towed above the gap, and an opportunity was awaited to make a second attempt at sinking it, but on account of strong currents and high water which prevailed, no such attempt was made up to the end of the year.

In addition, for secondary hurdle No. 4, a shore crib 60 feet long was constructed.

A shore crib 105 feet long was constructed for secondary hurdle No. 3, and was sunk April 21, on which day the repair of the other break in the same line was begun. In this work, the piling was entirely replaced and the line almost braced, when a sudden rise in the river, bringing with it great quantities of drift against this new work, forced it out and, at the same time, scoured the bottom until the water on the line of the hurdle reached a depth of 40 feet.

As it was impracticable to drive piles in such depths of water with a strong current, a new line was begun east of the break, and running up stream to a point 150 feet above the gap and thence back to the line, meeting the hurdle west of the gap. This line was chosen on account of the depths of water over the greater portion of it having been found not to exceed 20 feet.

A row of drift piles was added to the line, which was entirely completed, with the exception of wattling, to within 100 feet of its proposed point of junction with the old work on the west side of the gap, when instructions were received (June 13) to close work until after the high water had passed.

The equipment having been secured, the laborers were discharged, only sufficient force being retained to tend to the idle plant and keep the crib for hurdle No. 4 free from drift, and to load several rafts of piles which were on hand on barges.

In the prosecution of these works great annoyance has been caused by the high water and the drift, which has run in large quantities. Especially has this latter been felt in the care of the crib for hurdle No. 4 and in the repair of No. 3, where, at a number of times, the whole force has been engaged for a day and more at a time in clearing the line so that the work could be carried on. At present such a mass of drift has accumulated in front of the new work in this line that it never will be possible to wattle it.

During the season the force of men employed at any one time has never exceeded seventy-five, and it has averaged about fifty.

In closing, I desire to express my thanks to Mr. J. L. Duffy, assistant engineer, for his valuable assistance in the prosecution of the work, and also to Mr. S. B. Cady, assistant engineer, who was connected with the work during the first half of the year.

Very respectfully, your obedient servant,

WM. S. MITCHELL,
Resident Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

5.

TWIN HOLLOWS, EAST BANK.

REPORT OF MR. JOHN O. HOLMAN, ASSISTANT ENGINEER.

SAINT LOUIS, MO., *July* 17, 1883.

SIR: I have the honor to submit the following report of the operations for the protection of the bank at Twin Hollows, east side, for the fiscal year ending June 30, 1883.

The construction of the low-water mattress by last year's work had nearly reached Station 69, although not placed further than 59. During this year, under the direction of Mr. C. V. Mersereau, it has been completed to Station 86, which by your direction was fixed as the limit of the protection mattress at Twin Hollows, east side. This limit was reached by the low-water mattress August 11; by the medium stage protection October 19.

The substance of this report is taken from the report rendered to you by Mr. Mersereau, January 17.

Nine hundred and sixty-four linear feet of low-water mattress was hanging from the mooring barge June 30, 1882, with the mattress gang working at its lower end. Preparations were made to sink the mattress about the 1st of July, but the rising river prevented its being placed at that time. The construction was continued until July 14, when the water had subsided sufficiently to allow it to be placed. It extended from Station 59 to Station 74, making a length of 1,500 feet. In placing, a small break occurred near Station 70, the outer edge doubling under; but when properly loaded it came back into position and was placed in good condition.

A log boom extending from the outer end of the mooring barge about 350 feet up-shore was used to protect the mooring barge and head of the mattress from drift-wood. The rising river carried so much drift-wood that it broke the boom, and five empty barges were used in its place.

On July 3 the drift-wood which had passed beneath the barges collecting under the mooring barge and the head of the mattress, parted several lines to the mooring barge and caused it to push toward shore with such force as to ride over the guide piles, breaking a large spar and tearing the capstan completely off the barge. The mattress also crowded over the piling toward the bank for about 500 feet downstream. This movement allowed a large portion of the drift to escape, thus easing the strain on the head lines. The inner edge of the barge now rested against a large tree, and was in better condition to hold than before swinging in to the bank.

As the water fell the barge was lowered onto the top of a pile. As there was about 1,350 feet of mattress suspended from the barge it could not be moved, and the pile was forced through the bottom. A bulkhead was built around the pile and packed with bags partially filled with earth. No trouble was experienced from the leak after the barge had once been pumped out.

In sinking this section of mattress all of the head lines of the mooring barge broke after the mattress had been partially loaded, allowing the head of the mattress to sag down-stream about 50 feet before it could be loaded sufficiently to hold it in place. The bank under the upper end of the mattress had caved away to such an extent that the head of the mattress when placed was but little inside of the line of low water. The water had a depth of from 40 to 65 feet and a surface velocity of about 5 miles per hour.

A section of 1,210 feet was placed August 12. As the section placed in July had passed beyond the point from which the channel left the east bank, the 1,210 foot section carried the mattress barge into comparatively shallow water and completed the mattress work at Twin Hollows, east side. The placing of this section was easily made, as the inner edge had already settled to the bottom in two places of about 100 feet each.

From July 1 to August 11 the mattress was extended 1,516 feet; the number of working days between these dates was thirty-four, giving a daily average of about 44 linear feet per day. The number of days worked on the mattress was twenty-nine; this would give an average of 52 feet per working day. The greatest length constructed in one day was on August 10, when 130 linear feet was made. The small daily average is partially due to the use of dry brush, as the high water prevented fresh brush from being obtained. The number of weaving-poles varied from twenty to thirty-three, according to the size of brush furnished for the construction.

On July 1, 1882, the medium-stage protection had been extended from Station 0 to Station 22, from Station 35 to Station 37, and from Station 48 to Station 49+50.

But little work was done on the medium-stage protection until the completion of the low-water mattress in August. It was then extended to Station 59, and from Station 61 to Station 86+25.

From Station 54+80 to Station 58+80 a medium-stage protection mattress was constructed to bring the mattress work into the line of low water and prevent further caving between these points. The medium-stage protection varies in heigh

with the nature of the bank; between Station 22 and Station 49 it is up to about the 14-foot stage; between Station 49 and Station 59, also between Station 61 and 73, to the 10-foot stage, and from Station 73 to Station 86+25 to the 12-foot stage.

The space between Station 59 and Station 61 was without medium-stage protection until May; with that exception to Station 86+25 was placed by October 19, that space being left because of the perpendicular bank. A barge load of riprap was placed between Stations 59 and 60 May 4, and one between Stations 60 and 61 on May 19.

The entire length of the medium-stage protection is 8,625 feet, of which 6,075 feet were constructed during the year.

The high water of July left very large deposits of sand from Station 0 to Station 45. From Station 3 to Station 25 but few of the guide-piles will stand in the water with the river at a 14-foot stage, and some are entirely buried. Between Station 50 and Station 73 a deposit of from 2 to 5 feet of sand was left on top of the bank, but no fill took place along the slope.

Two sets of portable quarters were in use from July 1 until September 15, when one set was transferred to Chesley Island, and the last of the same month the second set was transferred to the same place. Three quarter-boats were in use during part of July and August. Quarter-boat No. 4 was retained until October 19, when the remaining force was taken to Chesley Island.

The tracing of the progress map accompanying this report shows the condition of the work June 30, 1883. The soundings in red were taken August 1, and reduced from 13.3-foot stage to 20.2-foot stage, which was the stage when the soundings for this year's report were taken.

Very respectfully, your obedient servant,

JOHN O. HOLMAN,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

6.

PULLTIGHT.

REPORT OF MR. JOHN O. HOLMAN, ASSISTANT ENGINEER.

PULLTIGHT, ILL., *July* 7, 1883.

SIR: I have the honor to submit the following report of the operations at Pulltight during the fiscal year ending June 30, 1883:

The repair of the hurdle at this point and its extension towards the head of Beard's Island was placed under my charge by your order of March 19, 1883.

During the season of 1882, while under construction, these hurdles were considered as a part of the improvement at Twin Hollows, east side, but the order also changed it to a separate work, calling it Pulltight.

A primary and a secondary were constructed under the charge of Mr. C. V. Mersereau, assistant engineer, during July, August, September, and the first part of October, 1882.

A small break in the primary near its lower end was discovered October 23, and Mr. William S. Mitchell, assistant engineer in charge of Twin Hollows, west side, was ordered to repair it. This repair and its extension a short distance occupied a small force the balance of the working season of 1882.

For a detailed account I have extracted these portions of the reports of Twin Hollows, east side, rendered during January, 1883, by Messrs. Mersereau and Mitchell, that referred to the construction of these hurdles:

"During the month of June the water was making such headway down the chute behind Beard's Island that it was decided to cut it off by the construction of a hurdle line. The line adopted extended from the head of the towhead above Beard's Island to a point on the Illinois shore about 2,000 feet up-stream. The work was begun the first week in July at the Illinois shore near Station 141. The current was very strong and the water from 30 to 35 feet deep for 800 feet of the line. On Thursday, July 13, forty-five piles driven next the Illinois shore were washed out, leaving five piles standing at the outer edge of the line; the drivers were then placed further over on the line in shallow water. As the water was gaining in depth very rapidly near the shore, this line was abandoned, and six drivers were started on a secondary line directly across the chute and about 300 feet below the head of the towhead. This line was about 850 feet long, and was located with a view of closing the chute as soon as possible. The piles driven caught the refuge brush from the mattress-barge above, and the water commenced shoaling immediately both above and below the line, excepting narrow channels close to the bank at each end of the line; as the outside of the towhead was caving very rapidly, a revetment mattress 600 feet long and 45 feet wide was constructed and placed.

"On July 26 all of the piling was completed, with the exception of about 150 feet near the middle of the second row, where the water was too shoal to allow a driver to work. Considerable delay occurred in the construction of the line for the want of piles. About 600 feet of the foundation mattress was built in position, as the water had fallen sufficiently to allow the men to work on the sand-bar formed by the hurdle. The line was completed about the middle of August. The channel close to the island filled up nearly even with the bar as soon as the drift accumulated against the piles.

"The large bar above Beard's Island threw a strong current against the Illinois shore between Stations 128 and 150, causing the bank to cave badly. In order to stop this a primary hurdle was constructed from Station 113 to the first small bar below. Two drivers worked on this line, which had a length of about 1,650 feet. This line was completed about the 1st of October.

"On October 23, 1882, a break 100 feet wide was discovered in the hurdle about 120 feet from the lower end of the line. On examination it was found that the current had washed under the mattress and had forced out the piles and wattling, scouring a deep hole immediately behind the line. The damage done was entirely local. The current, after passing through the hurdle, soon lost its force, and, beyond a slight washing of the Illinois bank, did no harm. Neither the lower hurdle nor the work at Beard's Island were threatened.

"On sounding the mattress was found still in place, although not down on the bottom. Stone enough was thrown on it to force it down and hold it close to the bottom, and the scour immediately stopped.

"Two pile-drivers were placed at work, and piles were redriven in the main row, to be used as brace-piles, and a hurdle-row was driven 18 feet in front of them, and curving back to the main line after the ends of the gap were passed. The piles were braced and strengthened by a top-stringer. A mattress was placed on the whole length of this new line, and the hurdle was wattled, effectually closing the break.

"The water having also scoured around the end of the hurdle, a mattress 110 feet long by 20 feet wide was sunk across the channel to the bar.

"It was afterwards decided to carry the hurdle itself to the bar, and a pile-driver was placed at this work November 29. The piling for this extension was completed for 200 feet, reaching the bar, and the piles were braced and top-stringers were bolted to them.

"A mattress 205 feet long by 20 feet wide was constructed and sunk over this new section, when the work closed for the season.

"It only remained to wattle the piling to have entirely completed the extension.

"All material and tools were brought from Twin Hollows, west bank, and all laborers were sent across in small boats, returning at noon and night to their quarters on the west side."

The passage of the ice gorges in the spring damaged both the primary and the secondary hurdles. An examination, made March 24, showed that the primary below Station 11, Station 0 being at the head of the line, had been carried away, and that a break had occurred from Station 1+50 to Station 3. The tops of all the hurdle-piles between Stations 3 and 11 had been broken off at the stringers, and in several places the wattling had been carried from the piles. The secondary was also damaged very badly; 600 feet of the 850 constructed was gone.

From the rise of the river in the spring a strong current had formed between the bar and shore, passing to the river again in front of the towhead, resulting in a very heavy scour to the towhead, the shore-line receding fully 1,200 feet to the 1st of April. The work of repairing the primary began April 1.

A force of two drivers and a complement of seventy-five men was allowed for the work at Pulltight by the superintending engineer. By April 14 the break at Station 2 was redriven, and the line repaired to Station 11. Four days later the driving in the extension to the bar reached Station 15. A space of nearly 600 feet was left for the passage of the steamer Humphreys, and the line from Station 20+70 to the bar, Station 28+60 was driven by May 8. The 600-foot gap was closed by June 8.

The following table gives the amount of work done on the primary during its construction in 1882 and 1883:

Kind of work.	1882.	1883.	Total.	Complete to station.
Piling, drift-row		2,860	2,860	
Piling, hurdle-row	2,055	1,910	3,965	28+60
Piling, brace-row	2,055	1,910	3,965	
Mattress	2,110	1,850	3,965	27
Wattling	1,910	75	1,985	11
Stringing	2,055	2,860	4,915	28+60
Bracing	2,055	2,200	4,255	24+35

Two drivers were in continuous use from April 1, to June 16. In that time 1,017 piles were driven in six hundred and seventy hours, a rate of 1.52 piles per hour. While repairing the line most of the piles were sharpened and driven with the hammer, the presence of the old foot-mattress preventing the use of the jet-pipe.

From Station 12 to the bar the driving was comparatively easy, except in closing the gap from Station 17 to Station 21, when the strong current caused by the rise in the river made the driving very difficult.

One thousand eight hundred and fifty feet of foot-mattress for the primary line was constructed with an average width of 55 feet. About half of it was built of a double layer of brush wired to a grillage of poles, but from Station 21 to the bar the form was changed to a woven mattress. It was woven on small flats fitted with ways, the piling in the three rows being cut to such a height as would just allow the weaving of the brush over their tops. With strong, pliable brush this form is more rapidly constructed and easier handled than the old form, but with small or weak brush the construction is slower and the mattress too weak for sinking in a strong current.

A mattress for the protection of the bank at the head of the primary hurdle was constructed during May, extending 200 feet above the line by 45 feet in width, and 145 feet below the line by 25 feet in width.

The stringers of the drift and hurdle rows were hung after the sinking of the foot mattress, unless the current was very strong, when they were hung immediately after the driving of the piles. The stringer of the drift-row was placed about 2 feet higher than on the hurdle-row, so that all the drift passing over the drift-row would clear the hurdle-row.

Driving on secondary No. 1 was begun June 8. Only eighty-five piles had been driven by the 14th, extending the line 200 feet from the shore end, when the superintending engineer ordered the closing of the works during the high water.

In April the towhead caved very little from the strong current passing across it, but during May the shore-line receded 600 feet. The secondary hurdle of 1882 also suffered, as all except 100 feet at the shore end was carried away. A mattress 60 feet wide was begun June 11 for the protection of the towhead during the construction of the hurdles, but only 100 feet was constructed and placed before the closing of the works, June 16.

On the tracing accompanying this report last season's work, carried away by ice, is shown by a red line. This season's work, from Station 11, is shown in black.

Drivers Nos. 10 and 21, ten skiffs, three yawls, seventeen small flats, barge-flats 28 and 32, with quarters, and the steam-launch Florence have been in service since March 27.

The *Florence* was sunk June 15, but was raised the same day with very little damage.

Appended are tables giving the service of the plant, and the material expended in construction work during the season of 1883.

I am indebted to my assistants, Messrs. A. F. Frois and B. E. Johnson, for the prompt and able manner in which they have discharged the duties assigned them.

Very respectfully, your obedient servant,

JOHN O. HOLMAN,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

7.

BEARD'S ISLAND.

REPORT OF MR. J. E SAVAGE, ASSISTANT ENGINEER.

SAINT LOUIS, MO., *July* 6, 1883.

SIR: I have the honor to transmit herewith a report of the operations carried on at Beard's Island, Illinois, with a view to improving the Mississippi River, for the fiscal year ending June 30, 1883.

I assumed charge of the work as resident engineer at this locality in accordance with your orders, dated October 18, 1882, relieving Mr. J. W. Record, who was in charge up to that time.

The work performed at this locality since the last annual report has been in the line of bank protection only, and the methods pursued were in accordance with the plan adopted in 1881 and with the operations previously reported, except in some minor details of construction.

This plan embraced a low-water mattress 120 feet wide woven upon a frame-work of willow poles, to be sunk with the inner edge at standard low water; a medium stage protection consisting of a layer 1 foot thick of riprap stone extending from

the edge of the mattress to 16 feet above standard low water, and the planting of willows for high-water protection.

Of these three classes of work the former has been practically completed, the second only partially, and no work has been commenced on the last.

On account of the increased velocity of the current encountered along the lower half of the island, it was found necessary to build a stronger mattress than was originally designed, and to sink in some places a medium stage mattress where the irregularity of the shore-line rendered it impracticable to follow the line of standard low water. Otherwise no deviation was made from the original plan.

Very little work was done in July on account of high water, and in August and September progress was delayed, by a succession of accidents and losses in the construction and sinking of the low-water mattress, accounted for by the increased velocity of the current, and the fact that the work was almost directly in the path of passing vessels. Work was continued until December 7, and in the last two months good progress was made. No work of improvement has been done since that date.

Under the headings of "low-water protection" and "medium-stage protection," and the subheadings of "grading" and "medium-stage mattress," the detailed progress of each division of the work is shown.

LOW-WATER PROTECTION.

At the date of the last annual report the island was protected by low-water mattress from Station 0, at the head of the island, to Station 35 + 50, a distance of 3,550 feet, and a section of mattress 540 feet long had been constructed and was suspended from the mooring-barge on the water's surface.

The river rose very rapidly during the last days of June and the first of July, covering the entire upper portion of the island and rendering it necessary to discontinue weaving and to use a large proportion of the force in removing the office to higher ground and transferring the movable property to quarter-boats.

Sunday, July 2, the drift-wood began to come down stream so rapidly that quite a large gang of men was necessary to keep it from accumulating on and breaking the mooring lines. An enormous amount collected under the mooring barge and the head of the mattress, and the strain upon the lines became so great that it was decided to attempt to sink it as the only possible chance of saving it. The usual preparations were made and precautions taken. Extra barges were anchored at the outside edge and a number of extra mooring lines attached, but the loading of the mattress had hardly commenced before the lines began to part, and almost immediately the mattress broke away.

The stage of the river precluded the possibility of continuing work, and the greater part of the force was discharged, enough being retained to take proper care of the plant.

Operations were resumed with a small force July 21. A new mattress was begun at Station 35 + 50 as before, and work continued on the same until August 28, at which time 1,115 linear feet had been woven, the design being to build it continuously and to sink 1,000 feet of it about September 1. The first 250 feet of it had been built of dry brush, and was subjected to a stronger current than any previous mattress except the one lost during the high water. The upper portion showed signs of weakness the morning of the 28th, and orders were received to sink it as soon as possible. Stone was ordered and preparations made to place it the same morning; but before the ways-barge had been taken out a line attached to the outside edge, about 200 feet below the mooring barge, parted, disclosing a break, which extended rapidly in a zigzag line across the mattress. Each line parted in succession, allowing the mattress, ways-barge, and brush-barge to be swept away by the current. Some 915 linear feet of mattress were lost, but nearly all the lines were saved and the barges caught at "Jim Smith's."

As soon as practicable another mattress was started opposite Station 37 + 50, and, in addition to the regular method of construction the mattress was strengthened by the addition of splices about 8 feet long and the same size as the weaving-poles wired over each joint of the latter. Extra fore-and-aft stringers were placed between the four outside poles, running the entire length of the mattress, and wired to the brush at short intervals; and also cross stringers woven with the brush were used about every 100 feet. A strip 750 feet in length was so constructed, and successfully placed on September 16.

Weaving was commenced on another section on the 19th. This strip was almost directly in the channel which, crossing from the Missouri shore, threw its current obliquely against the bank at this point and forced passing vessels in-shore in such a manner as to seriously impede the progress of the work. Several boats having run against the mooring barge and knocked it out of position, we were obliged to sink the mattress when only about 350 linear feet were completed. Another mattress begun September 29 shared a similar fate when about 150 linear feet were woven,

and as it seemed impossible to both construct and sink a mattress here with so much interference from steamboats and the swift current, it was decided to construct a mattress further up-stream in comparatively still water, float it to the position desired, and sink it. By this means the sinking might be accomplished in a few hours and the trouble from passing boats avoided. A section 325 feet in length was so constructed, but in attempting to float it down to the required position some of the lines parted, and before its progress could be checked it was carried about 150 feet too far. It was made fast here in the usual manner, and sinking commenced the following day, but it had become considerably wrenched and weakened by coming in contact with the guide-piles while being floated down, and during the sinking process broke into several pieces, and a large proportion of it was lost. A strip 175 feet in length was picked up by the steamer Humphreys, towed to Chesley Island, and made use of there, but the small amount sunk at Beard's Island formed no efficient protection.

The bank below the last-mentioned mattress having wasted away nearly 200 feet, the next one was commenced nearer shore, lapping the previous one on the inside edge and forming a re-entrant angle in the protection. Weaving was commenced October 21, the design being to build a continuous mattress. About 1,200 linear feet were completed before an attempt was made to sink any, and on November 13 1,050 linear feet were successfully placed. The weaving was continued on the same section until November 21, 200 additional feet having been placed meanwhile, and the mattress had passed the end of the island proper and was subjected to a very strong cross-current, and an immense strain from accumulated drift. On the afternoon of the above date the ways of the mattress-barge broke close to the gunwale, and made it necessary to launch and sink the mattress and repair the ways before continuing. The entire section thus completed was 1,480 feet in length. Weaving was resumed two days later and continued until December 6, at which time work was suspended for the season, the river being filled with floating ice. This section of 680 linear feet was successfully placed, and completed a continuous low-water protection from Station 0 to 75 + 50.

The total amount of 120-feet-wide mattress constructed in the fiscal year was 4,850 linear feet, but in addition to this a mattress 100 feet wide—mentioned under "Medium-stage mattress"—and 325 feet long was built below Station 75+50, being partially low water and part medium stage protection.

Statistics of progress computed on the 120-foot mattress commenced at Station 49+75, and ending with the year's work at Station 70+55, give the following results: The total number of hours' labor was 25,752, the number of days actually worked thirty-nine, and the number of linear feet constructed and placed 2,160. These figures give an average of 0.84 linear foot per man for each ten hours' labor, and show an average of sixty-six men building and sinking about 55 linear feet per day.

MEDIUM-STAGE PROTECTION.

The medium-stage protection of riprap stone had been carried June 30, 1882, to Station 16 + 50, 1,650 linear feet from the head of the island. During the latter part of July this work was extended to Station 18, the whole strip being carried to the required stage, 16 feet above standard low water. The river fell so low in August that it was impracticable to continue this section on account of the bar which had formed outside the line of guide-piles, and work was commenced at Station 28, leaving 1,000 linear feet of bank that has received no riprap, and continued from time to time as stone could be procured until November, when it proceeded almost continuously till the end of the season. Most of it, however, was carried only to the 10-foot stage or 6 feet above standard low water.

The total length of bank revetted with stone during the year was 3,500 feet, of which 850 linear feet was carried to the required stage and 2,650 linear feet to the 10-foot stage. The former was between Stations 16 + 50 and 18, Stations 28 and 33, and Stations 40 + 50 and 42 + 50; the latter extended from Station 33 to Station 35, from Station 35 + 50 to Station 40 + 50, from 42 + 50 to Station 59, and from Station 62 to Station 65.

GRADING.

The steep bank inside the guide-piles below Station 35 necessitated excavation and grading before the medium-stage protection could be placed. For this purpose a steam hydraulic excavator was employed during the last of October and first of November, grading 1,043 linear feet of bank between 14 and 20 feet high to a slope of 2 to 1. The number of cubic yards excavated was estimated at 15,452; the total cost of labor, supervision, and fuel, $217.77, making an average cost of 1 1/10 cents per cubic yard, and about 21 cents per linear foot of bank graded. A small amount of grading was also done by hand labor, but the above cost represents only that done by the excavator. The hydraulic excavation was carried on fifteen days, and its economy and rapidity were fully proven. Very little difficulty was experienced in cutting the bank to the desired slope.

MEDIUM-STAGE MATTRESS.

During almost the entire year the current followed and seemed to keep just ahead of the completed protection, cutting the bank in an irregular manner, and making it impossible to sink the inside edge of the mattress at the line of standard low water. This cutting was especially active between Stations 44 and 50, and it was found necessary to build a medium-stage mattress for this distance of an average width of 80 feet. The construction of this mattress was similar to that of the hurdle-foundation mattress, and consisted of two layers of brush placed at right angles with a strong grillage above and below, the whole being lashed and wired together on large flats and sunk in place.

A similar mattress, 60 feet in width, was commenced October 30 at Station 64, designed to protect the low bank or bar below the island proper, where the slough had filled to about the 15-foot stage. About 900 linear feet were built of this width and a triangular strip 200 feet long with a 40-foot base added at its upper extremity to widen it and to lap the edge at the low-water mattress. The design was then changed to a 100-foot wide mattress, to be woven on temporary ways placed on large flats. This mattress protected the bank both as low water and medium stage mattress, but in the summary is regarded as low-water protection; 325 linear feet were constructed, extending from Station 72+50 to 75+75.

The total length protected on the bar was 1,175 feet, and the dimensions of each mattress less than 120 feet were as follows: between Stations 44 and 50 a section 600 by 80 feet; between Stations 64 and 73 one 900 by 60 feet, and the triangular piece mentioned above; and below Station 72+50 a section 325 by 100 feet.

The accompanying sketch, Plate V, shows the relative position of the bank at the beginning and end of the year, the comparative depths of water, and the extent and location of the work constructed.

The following table shows the amount and cost of the material expended on each class of work, and a statement of the amount of each kind completed to date:

Material.	Low-water mattress.	Medium stage protection.		Total.
		Mattress.	Rip-rap.	
Brush.....cords..	4,117.01	1,149.20	.....	5,266.21
Stone.....cubic yards..	2,203.95	667.49	3,362.19	6,233.63
Piles.....linear feet..	14,832	5,909	.....	20,741
Piles.....number..	423	161	.....	584
Spikes, 8-inch.....pounds..	5,250	.....	.....	5,250
6-inch.....do....	1,450	1,350	.....	2,800
Wire, No. 14.....do....	.....	1,500	.....	1,500
No. 12.....do....	7,755	25	.....	7,780
No. 10.....do....	550	.....	.....	550
No. 9.....do....	1,005	.....	.....	1,005
Nails, 20*d*.....do....	655	100	.....	755
8*d*.....do....	200	.....	.....	200
Sisal rope.....do....	1,201	1,702	.....	2,903
Sisal yarn.....do....	.....	110	.....	110
Round iron.....do....	203	.....	.....	203
Screw-bolts.....number..	20	.....	.....	20
Drift-bolts.....do....	300	.....	.....	300

Kind of work.	1881 to 1882.			1882 to 1883.			Total protected to date.
	Constructed.	Laps and losses.	Total protected.	Constructed.	Laps and losses.	Total protected.	
Low-water mattress	4,500	950	3,550	5,175	1,345	3,830	7,380
Medium-stage mattress	.....	.....	.....	1,500	.....	1,500	1,500
Medium-stage riprap, 10-foot stage	.....	.....	.....	2,650	.....	2,650	2,650
Medium-stage riprap, 20-foot stage	1,650	.....	1,650	850	.....	850	2,500
Grading	.....	.....	.....	1,043	.....	1,043	1,043
Primary hurdle	960	.....	960	.....	.....	.....	960

No work of improvement has been done since December 7, 1882; but, with the exception of a slight grading action above the partially completed protection of riprap, no cutting or caving of the bank has occurred, while the soundings show a general

fill from sediment deposits the entire length of the island. Previous to the commencement of the protection work the island was wasting away, by the action of the current, at an average rate of about 10 feet per week for its entire length, and its present condition proves the efficiency of the work.

After taking charge of the work in October, I was ably assisted by Mr. C. P. Mitchell, assistant engineer, to whom I desire to return thanks.

Very respectfully, your obedient servant,

J. E. SAVAGE,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

8.

CHESLEY ISLAND.

REPORT OF MR. C. V. MERSEREAU, ASSISTANT ENGINEER.

CHESLEY ISLAND, MO., *July* 7, 1883.

SIR: I have the honor to submit the following report of operations at Chesley Island for the year ending June 30, 1883:

The bank protection at Chesley Island was begun on September 15, 1882, and continued until December 14, 1882, when the work was suspended on account of the close of navigation.

On March 19, 1883, orders were received to resume work as soon as practicable. The quarters were occupied on March 22, and active operations were resumed on the arrival of material on March 26, 1883, and continued until June 15, 1883, when the high water caused the suspension of active work.

There were constructed during the year ending June 30, 1883, 4,305 linear feet of low-water mattress 120 feet wide; 4,464 linear feet of low-water mattress 120 feet wide were placed, of which 174 linear feet came from Beard's Island; 3,475 linear feet of medium-stage protection carried up 16 feet above standard low water and averaging about 65 feet wide; 1,010 linear feet of medium-stage protection carried up 8 feet above standard low water and averaging about 25 feet wide; 2,760 linear feet of grading cut about 36 feet wide and 18 feet deep; 350 linear feet of medium-stage protection mattress 50 feet wide; 550 linear feet of low-water mattress about 40 feet wide; 759 piles driven; 720 feet foundation mattress 50 feet wide.

Preparations for the bank protection at Chesley Island were begun about the middle of September, 1882.

One set of portable buildings was taken from the works at Twin Hollows, east side, and erected on the island about a quarter of a mile below the head, this being the highest ground available for the purpose.

This portion of the island was covered with a thick growth of young cottonwoods and sycamores, which had to be cleared off before the ground was available for the erection of the quarters.

Pile-driver No. 14 was brought from Twin Hollows, east side, on September 19. Two clumps of four piles each were driven about 400 feet above the head of the island and in the shoal water across the head of the chute. A third group of five piles was also driven just above the high bank at the head of the island and firmly braced together. By resting the inshore end of the mooring barge against the third group of piles and making the head lines fast to the two clumps of piles above the island the mattress work was commenced at the head of the island.

Mattress barge No. 3 arrived from the engineering depot September 22, and the construction of the low-water mattress, 120 feet wide, was immediately begun. Twenty-five weaving poles were put in at the commencement, but the brush being large, the number was reduced to twenty-three. A grillage of poles was placed under the head of the mattress to strengthen it, but was discontinued after the first 50 feet, as it offered too great a surface to the resistance of the current. After dropping the grillage four stringers were run along under the outside edge of the mattress and a cross-piece put in every 100 feet to give good fastenings for mooring lines.

On October 19, 840 feet of mattress was placed, and about 400 feet left floating. The mattress was continuous, the inclined portion being held in position by lines from a mooring barge placed across the mattress and from shore.

The soundings made during the construction of this portion of the mattress gave an average depth of about 24 feet; on placing the mattress the depth was about 35 feet, the stage of the river being about the same.

The placing of the remainder of the mattress was done at intervals, the mattress barge generally being from one to three days' work in advance of the mooring barge. Sufficient stone was usually kept on the mooring barge to sink the whole of the mattress floating in case of an accident.

On November 4 a small break occurred at the outer edge of mattress at station 20, being just below the mooring barge. In sinking on the following day the break was extended in to about 40 feet; the corner doubled under and tore a triangular shaped piece about 40 feet by 100 feet from the outside edge of the mattress.

On December 5 the mattress was finished and placed to Station 43+05. It lapped about 15 feet on the piece of mattress 174 feet long that floated down from Beard's Island on October 14, and which had been placed as far down the bank as it was thought necessary to extend the mattress work.

The total length of the mattress work is 4,464 feet, of which 4,305 feet was constructed continuously and placed with but one small break in it. This break extended only one-third across the mattress and impairs its value as a protection but little.

The total number of working days from the commencement to the finishing of mattress was 64. This gives a daily average of 67 feet per working day. The number of days spent on construction was fifty-nine, of which six half days were lost on account of bad weather, leaving fifty-six days worked; this gives an average of 77 feet per day worked. On fourteen of the fifty-six days worked the average number of hours was less than two hundred, or less than one-third the number of hours of a full gang. The largest amount constructed in a single day of nine hours' work was 126 feet. Two days gave 120 feet each, and four other days gave over 100 feet each.

The mattress was placed in from 24 to 30 feet of water on the outside edge, with a stage of water of about 6 feet above standard low water. The steamboat channel was close to the bank and the current had a velocity of about 3½ miles per hour. The soundings taken during the construction showed the water to be of nearly uniform depth on the outside 90 feet of the mattress.

In compliance with your orders of March 19, 1883, preparations were at once made for the construction of a low-water mattress, 40 feet wide, to be placed on the west side of the head of the island.

On March 27 pile-driver No. 5 was received and commenced driving piles from which to suspend the mattress, about 100 feet above the head of the island. The mattress was commenced on March 31 and continued until April 10, when the entire section, about 550 feet long and 40 feet wide, was placed in from 18 to 34 feet of water, the Saint Louis gauge reading about 18 feet. The mattress was woven on eight poles, the ways being carried on five small flats.

The medium-stage protection had been placed from Station 0 to Station 39 before the suspension of the work in the winter. It had an average width of about 30 feet, and extended from the edge of the low-water mattress to about 6 feet above standard low water, with the exception of a space of about 100 feet at the head of the island, which extended about 12 feet above standard low water.

Work was resumed on the medium stage protection on March 26, 1883, and stone has been placed wherever available during the season. The riprap from Station 0 to Station 28+90 has been extended up the bank to 16 feet above standard low water, and has an average width of about 65 feet. A large portion of this work was done at a high stage of water, and will probably require some leveling off when the water will permit.

On the west side of the head of the island 585 linear feet of riprap, extending from the edge of the small low-water mattress to about 14 feet above standard low water, was placed. The stone could not be carried to the 16-foot stage on account of a bluff bank above the 14-foot stage, but sufficient stone was left along the upper edge of the work to carry it to the 16-foot stage as soon as the bank grades back.

A medium-stage protection mattress around the head of the island, to protect it from caving and to prevent the undermining of the head of the low-water mattress, was begun October 27, 1882. This was commenced about 400 feet above the head of the island, and a strip of about 50 feet wide extended down nearly to the head of the low-water mattress. Owing to the scarcity of brush the mattress was dropped and three barge loads of stone were placed on the channel side of the island above the head of the mattress.

On November 15 the hydraulic excavator arrived from Beard's Island and began work at the head of the island; it worked down the bank to Station 27+50. The average height of the bank excavated was about 18 feet; the grade of 2 to 1 could not be cut on account of the lower stratum of the bank being coarse sand, which washed out very rapidly. The average slope is about 1½ to 1, but from the edge of the mattress to the top of the bank would give an average slope of over 2 to 1.

During the latter part of November a pile-driver was sent from Twin Hollows, west side, to be tried as an excavator. It was found to work well in cutting the bank, but the volume of water was too small to wash away the fallen earth with rapidity. About 50 linear feet a day could be graded with it.

The grading extended over about 2,800 linear feet; the average width of cut was about 35 feet, and the average height of cut 18 feet. This would give for amount of excavation about 32,600 cubic yards.

A hurdle line across the chute behind Chesley Island was commenced April 18, 1883, and work on it was continued until June 15, when it was suspended on account of high water.

The line was located about 1,000 feet below the head of the island, 700 feet below the mouth of the Meramec River, and about 100 feet above the towhead of First Island. One pile-driver (No. 11) was employed until May 18, when the second pile-driver (No. 20) was placed on the line. The line was commenced at the east or island end and pushed toward the Missouri shore. When about 500 feet of the line had been driven the driftwood ran so heavily that the pile-drivers were taken to the Missouri shore and about 300 feet of line driven from that end before the work was suspended.

Most of the driftwood in the river passed down behind the island, and a large mass accumulated there. On June 5 the driftwood, extending about 800 feet above the line, went out in a body. As the water was about 6 feet above the tops of the piles but little damage was done; 363 piles were driven, 10 stringers placed, and 720 feet of foundation mattress were placed, 580 feet of which were at the east end and 140 feet at the west end of the line; 240 linear feet at the west end of the line was braced with large poles at about the 27-foot stage. Fifty feet of curtain was placed at the east end of the line.

The location of the work was made from Station 17 of survey of 1874 and Station 20 as located by Mr. John O. Holman, assistant engineer, and was afterwards checked from Stations 23 and 25 survey of 1874.

The sketch transmitted herewith shows condition of the work on June 30, 1883. The soundings in red were taken December 4, 1882, and are reduced to same stage as those in black, which were taken June 30, 1883.

* * * * * * *

In closing, I desire to express my thanks to Mr. John W. Irwin, assistant engineer, for the very valuable assistance rendered and the interest he has taken in the work.

Very respectfully, your obedient servant,

C. V. MERSEREAU,
Resident Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

9.

"JIM SMITH'S."

REPORT OF MR. JOHN O. HOLMAN, ASSISTANT ENGINEER.

PULLTIGHT, ILL., *July* 7, 1883.

SIR: I have the honor to submit the following report of the operations at "Jim Smith's" during the fiscal year ending June 30, 1883:

The hurdles for the improvement at Jim Smith's include a primary and nine secondaries.

Construction work began at the upper end of the inclined primary June 1, 1882. During that month 1,500 feet of drift row, 900 feet of hurdle row, and 850 feet of brace row were driven.

July, 1882, opened with high water, necessitating suspension of work until the 17th. From then the work progressed continuously until the closure in the fall, which occurred the 6th of December.

Work was in progress on the primary, and the secondaries from one to seven, inclusive.

The following tables are given to show the amounts of piling, mattress, &c., constructed in each month on the different hurdles, ending with the totals constructed during the half year:

PRIMARY HURDLE.

(F to F, 3,820 feet + F to E, 13,325 feet = 17,145 feet.)

	July.	August.	September.	October.	November.	December.	Total.
Piling	840	1,270	930	3,300	1,005	.....	7,355
Stringing	800	1,250	600	3,375	1,405	.....	7,430
Mattress	680	1,270	600	950	2,000	300	5,800
Bracing	700	1,050	1,120	950	2,000	600	6,420
Wattling	300	1,500	600	520	2,400	.....	5,320

SECONDARY No. 1.

[870 feet long.]

	July.	August.	September.	October.	November.	December.	Total.
Piling	700	170					870
Stringing		470	400				870
Mattress	550	320					870
Bracing		870					870
Wattling		870					870

SECONDARY No. 2.

[1,940 feet long.]

Piling		1,440	250	200	500		2,390
Stringing			1,690	200	450		2,340
Mattress		1,140	550	200	450		2,340
Bracing			1,190	450	250		1,890
Wattling		340	600	700	250		1,890

SECONDARY No. 3.

[1,600 feet long.]

Piling		475	270	475	225		1,445
Stringing			745	475	225		1,445
Mattress		475	270	475	225		1,445
Bracing			475	745	225		1,445
Wattling			475	495	225		1,195

SECONDARY No. 4.

[1,250 feet long.]

Piling				325	250		575
Stringing				325	250		575
Mattress				325	250		575
Bracing					575		575
Wattling					575		575

SECONDARY No. 5.

[1,050 feet long.]

Piling				1,050			1,050
Stringing				1,050			1,050
Mattress				800	250		1,050
Bracing					1,050		1,050
Wattling					1,050		1,050

SECONDARY No. 6.

[1,300 feet long.]

Piling			580	170			750
Stringing			580	170			750
Mattress				750			750
Bracing				750			750
Wattling				750			750

TOTAL CONSTRUCTED.

	July.	August.	September.	October.	November.	December.	Total.
Piling	1,550	3,355	2,550	5,520	1,980	.....	14,955
Stringing	800	1,720	4,535	5,595	2,330	.....	14,980
Mattress	1,230	3,205	1,940	3,500	3,175	300	13,350
Bracing	700	1,920	2,785	2,895	4,100	600	13,000
Wattling	300	2.710	1,675	2,465	4,500	.....	11,650

When the river receded to a working stage on the 17th, construction work was begun. Two barges with portable quarters and two sets of portable quarters on shore, capable of accommodating three hundred and fifty persons, were then in use, although during the first week of July only ninety-nine persons were employed.

The high water flooded the men's quarters in the upper set of buildings, and caused the moving of the building of the lower set, but no other damage was done to them by the high water.

The seven pile drivers, Nos. 1, 2, 5, 7, 18, 19, and 21, then stationed at this work, were idle until the 12th of July, when four of them were used in pulling drift preparatory to driving, which was resumed on the 17th. No. 21 was taken to Twin Hollows July 21.

Three of the drivers were placed on the primary and two on secondary No. 1. Driving on No. 1 began at the shore end and was carried toward the primary, closing with it August 25, although on August 5 it was within 50 feet of closing, that space being left for the passage of the drivers and barges working above. After the drift had been cleared from the primary between Stations 9 and 9+50, that line was carried continuously down stream until August 5, having then reached Station 22, where the first break occurred in the line extending the 200 feet between Stations 19 and 21. This break was caused by the accumulation of drift coming from the caving bank at Beard's Island, the piling in the drift row breaking and carrying the hurdle row with it. The drift row above Station 19 was held by the floating mattress, which had then been constructed to Station 1-+50, although more drift had gathered above Station 19 than below. To prevent further breaks, piles were placed across the row connecting with the drift hurdle and brace piles, which braced the row during the building of the mattress and the placing of braces. This cross-bracing was continued with the driving of the line as far as Station 29, which was reached August 25.

It was then decided by the officer in charge to connect the work with the channel bar, and the drivers were moved to the bar, driving up stream, so as to connect some distance from the bar. Driving was also begun at the same time at the bar end of No. 2, working shorewards. In the mean time No. 2 had been driven since the 1st of August from the shore to Station 6+40, and also No. 3 since the 20th of August had been driven 350 feet from shore to Station 12+50.

These secondary lines were protected in a great measure from drift by the primary line, and in their construction only the hurdle and brace rows were used with cross-braces, but the stringers were placed on the hurdle row as soon as driven.

On Monday, the 28th, with the hurdle lines carried to about the distance as above mentioned, the mattress from Beard's Island, with two barges attached, managed to pass through without doing any material damage to the hurdle lines. The mattress, about 800 feet long, came down broadside on, with two barges attached to the river end, the shore end of the mattress striking the primary at about Station 23. Both barges swung around the end of the primary without striking, and were finally caught as they passed No. 3 hurdle. The mattress went through, breaking all of the lines fastened to it as it passed the different hurdles.

During July and August the employés, the maximum being 202, were mostly disposed of in two sets of quarters, one on barge No. 29 and the other on shore above hurdle No. 2. The quarters at the end of No. 6 hurdle were used only by a few. A set of buildings taken from Twin Hollows, east side, were erected just below the lower quarters during the first week of September, and were ready for use on the 7th.

As the *Humphreys* could not land at the upper buildings, it was decided to move them to the lower landing, and on the 15th they had been moved and were ready for use. The drivers were also increased in number from six to eleven during the first week of September by the arrival of No. 17 on the 4th, Nos. 8 and 11 from Cape Girardeau on the 6th, and Nos. 9 and 10 from Twin Hollows on the 7th. But even with the extra drivers and quarters less work was done in September than in August, on account of the chills and fevers then prevalent in the camp. It was near the end of September before crews could be found for all of the drivers.

A break of 250 feet in line No. 2 occurred between Stations 9+50 and 12 which, was repaired during September, and only from Stations 6 to 8 remained undriven.

The primary line was closed on the 21st, and by the end of the month it had been entirely finished from the shore to the bar except 500 feet of wattling between Stations 29 and 34.

Until the 21st all the driving had been done on secondaries 1, 2, and 3, and on the primary above F, but the drivers were then moved from the primary to hurdles 6 and 7, driving from the bar.

In October the drivers made the best showing, driving 5,520 linear feet of hurdle line. No. 5 hurdle, 1,050 feet long, was driven between October 9 and 21, in the week ending October 21, No. 4, began October 12, was extended 325 feet from the bar. No. 6 hurdle and the gap in No. 2 was finished on the 13th, the gap in No. 3 finished on the 20th, and 3,200 feet of primary driven between hurdles 4 and 7.

In November 1,980 linear feet of hurdle was driven, 850 of it on the primary between 4 and 7, 250 of it on No. 4, and the balance in repairing the breaks of the hurdle lines.

The force of laborers was more than doubled to keep the construction of mattress, wattling, &c., up with the driving. From 202 on September 1 an increase was made to 356 on October 1, and to 545 on November 1. To keep this force, three barges with quarters, one quarter boat, and three sets of quarters on shore were in use with a total accommodation for five hundred and seventy-nine men.

The rise in the river during the week ending October 21 caused a caving under the mattress at the bar end of the primary. As the mattress lowered, the bar began caving very rapidly. No. 2 hurdle gave way again between Stations 7+50 and 12, and No. 3 followed by breaking between Stations 6+50 and 8. The caving after it extended around the bar end of No. 2 on the 24th was very rapid. These breaks in Nos. 2 and 3 were repaired, as also another of 75 feet in No. 3 hurdle at Station 10. The final break occurred in No. 3, between Stations 13 and 14+25, the repair of which was in progress when the work was stopped.

The break at the end of the primary was, of course, due to the water crowded between the channel bar and the primary hurdle, but in the secondaries, when the water passed through the whole length of the wattling, these breaks were due to the undermining of the mattress.

The double thickness of brush as well as the stringers used in the construction of these foot-mats, render them too stiff to lay closely to the bottom unless loaded with over amount of stone; and in cases similar to hurdles 2 and 3, where the water was checked by the wattling and held between the bar and shore, it required but a short time to undermine the hurdle at some point, relieving the balance of the line by a washout.

A foot-mattress, constructed similar to the protection mattress, where the brush by weaving could be made double width instead of double thickness, would be better for resisting the scour.

Between point F and hurdle No. 4 on the primary, four rows of willows and one of cottonwoods were planted. This work consumed the time of a sub-overseer and sixty men from 9th to 28th of October. The willows and cottonwood cuttings were procured from the Illinois shore opposite the channel bar, and the wagons loaded with these brush cuttings were ferried across in flats at hurdle No. 4; 450 feet of the line was lost by the caving of the bar between Stations 0 and 4+50.

The steam-launch Florence has been in service since the 1st of August, rendering valuable service, in moving small flats, piles, and pile-drivers, although not worked to her fullest capacity on account of her light build.

Beginning with December, the force of laborers was rapidly reduced, the floating property transferred to Twin Hollows, and the property remaining left in charge of Wm. Lee, overseer.

The hurdles suffered greatly by the running of the ice in the spring.

The following table gives the length of the hurdle lines standing January 1 and April 1:

Hurdles.	Standing January 1.	Standing April 1.	Loss.
No. 1	870	300	570
No. 2	1,890	850	1,040
No. 3	1,220	320	900
No. 4	575	150	425
No. 5	1,050	270	780
No. 6	750	670	80
No. 7	100	100	.....
Total	6,455	2,660	3,795
Primary	4,575	2,875	1,700
Primary inclined	3,550	2,650	900
Total	8,125	5,525	2,600

Another break occurred in the primary from Station 2+70 to 5+50 the last of May. These changes are shown on the tracing accompanying this report. The full blue line on the primary to Station 7, with a broken line to Station 15, shows the length of line constructed to June 30. The dotted part was washed away by the high water of July, 1882. The dotted red lines on the primary and secondaries show the portions carried away since January 1, the full black lines, the portions of the hurdles now standing. The full green line to Hurdle No. 4 shows the length of willow-planting on the bar.

No construction work has been done this season. Two of the portable buildings, with their outfit, were placed on Barge No. 32 for service at Pulltight. The remaining property was transferred to the depot.

Very respectfully, your obedient servant.

JOHN O. HOLMAN,
Resident Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

10.

FOSTER'S ISLAND.

REPORT OF LIEUTENANT FREDERIC V. ABBOT, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., July 3, 1883.

SIR: I have the honor to transmit herewith my annual report upon the work done at Foster Island during the fiscal year ending June 30, 1883, with a view to improving the Mississippi River in that vicinity.

I assumed charge of this work on the 13th of June, 1883, relieving Mr. J. A. Worthen. My report covers the operations of the entire year.

A set of portable shanties for quarters was erected at Foster Island in September, 1882, with the expectation that the works near Cape Girardeau, Missouri, would be completed, and the engineer assistants and plant there in service would become available about the 1st of October. They did not arrive till October 25, and from that date till November 9 Mr. J. A. Worthen, the resident engineer, assigned to this locality, was engaged with his force in erecting shanties and making the necessary preparations for beginning a new work.

These preliminaries having been completed November 9, a mattress to protect the shore of the island below standard low water against the further advance of the river was begun as near the head of the island as a large sand-bar, which had formed during the preceding high water, would allow.

The head of the mattress was supported on piles instead of on a barge, as is the usual method, because the depth of water was slight, and the approach of freezing weather rendered it inexpedient to risk getting a barge hard aground in a position so exposed to running ice.

The width of the mattress, 105 feet, was 15 feet less than the standard, because no regular ways-barge was available, and the barge flat used for the purpose was not long enough to accommodate the usual number of ways. Care was exercised to sink the mattress so that its outer edge was 120 feet on the channel side of the curve of standard low water, so that in the future the zone 15 feet wide between the inshore edge of the mattress and this curve can be protected without difficulty.

But 580 linear feet of mattress had been completed and placed when navigation closed, and work was suspended for the winter. This occurred December 1, 1882, only twenty-two days after the work had been begun. Part of a barge-load of stone remained after the mattress had been placed, and this was distributed as medium stage revetment, near the upper end of the protected bank.

That so little was accomplished was largely due to many unfavorable circumstances. The force of laborers varied constantly between ten and fifty, no men remaining long enough to become expert, but all leaving after they had earned money enough to pay their passage south, where they intended to work on the lower river. The weather was severely cold.

Since December 1, 1882, no work of construction has been done at this locality on account of prevailing high water. The condition of the bank has been examined from time to time, and on April 30, 1883, the shore line was surveyed; it is shown on the accompanying Plate, No. —,* in a full line. The shore-line in 1881 is also shown, in

* Plate not forwarded.

dotted lines; that on December 1, 1882, in broken and dotted lines. The plate shows that the shore has receded between 100 and 200 feet, about ten acres having caved into the river.

The position and extent of mattress sunk is shown in broken lines; the stone placed as medium stage revetment is seen near the point M. M N is a chained base; its two extremities are located with reference to points 27 and 29 of the general survey of the Mississippi River between the Illinois and the Ohio rivers, made under this office.

Work will be resumed at this locality as soon as the river has reached a sufficiently low stage.

Following is a detailed statement of expenditures for labor and material.

DETAILED EXPENDITURES FOR LABOR AND MATERIAL AT FOSTER ISLAND, FOR FISCAL YEAR ENDING JUNE 30, 1883.

Low-water protection:

To labor, constructing mattress	$490 86		
To labor, sinking mattress	17 72		
		$508 58	
To brush		1,390 00	
To labor, driving piles	60 73		
To pile timber, sixty-six sticks driven	199 27		
To pile timber, eight sticks miscellaneous	24 16		
		284 16	
To stone		167 39	
To rope		33 35	
To wire		53 50	
To iron		2 27	
To nails		4 80	
To spikes		18 80	
To subsistence, service at locality	396 11		
To subsistence, provisions	472 74		
To subsistence, contingencies	94 28		
		963 18	
To equipment, steamer Anita	80 30		
To equipment, steamer Humphreys	134 88		
To equipment, pile-drivers	45 44		
To equipment, barge flats	68 22		
To equipment, skiffs	50 40		
To equipment, tools and appliances	92 60		
To equipment, quarters	218 40		
		696 24	
			$4,122 22

Mean stage protection:

To labor, placing stone		$20 25	
To stone		118 75	
To subsistence, service at locality	$20 85		
To subsistence, provisions	30 11		
To subsistence, contingencies	1 20		
		52 16	
To equipment, steamer Humphreys	16 86		
To equipment, quarters	8 40		
		25 26	
			$216 42

Engineering and contingencies:

To engineering	506 00		
To contingencies	649 06		
To general expense	241 50		
To surveys		1 16	
To telephone		36 96	
To office furniture		1 34	
To instruments		4 52	
			1,440 54
Total			5,779 18

Very respectfully, your obedient servant,

FREDERIC V. ABBOT,
First Lieut. of Engineers.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

11.

PIASA ISLAND.

REPORT OF MR. C. D. LAMB, ASSISTANT ENGINEER.

SAINT LOUIS, MO., *July* 6, 1883.

MAJOR: I have the honor to submit the following report of operations at Piasa Dam during the fiscal year ending June 30, 1883.

The chute on the Illinois side of Piasa Island had been used as the steamboat channel for several years, but has been run with constantly increasing difficulty on account of the large bar which had worked down across its head. When the river fell below a medium stage in August, 1882, steamboats were obliged to pass down the west side of the island crossing the dam near the Missouri shore. The crest of the dam was lower at other places, particularly near the island, but steamers could not get to and from these depressions with safety on account of shoal water above and below. Soundings taken August 26 showed but 6 feet of water on the dam in the available channel, the stage of the river at Alton being 9 feet above low water.

In accordance with your instructions of August 31, an effort was made to lower the crest of the dam by pumping the sand from beneath it with a Roy Stone dredge. Work was begun September 13, the hydraulic excavator described in the report of the Chief of Engineers for the year ending June 30, 1882, page 1604, having been equipped with a dredge arranged as follows: The tube of three-eighths inch boiler iron was 14 inches in diameter and 40 feet long, one end of which was suspended from a derrick and the other from a davit placed on the bow of the excavator. One-half the stream from the large pump passed through a section of hose into a piece of 3-inch gas-pipe fastened to the under side of the tube and terminated with a nozzle. This discharged at the end of the tube and formed the stirring-up jet. The other half of the stream from the pump was used as an inducing current. This passed through a section of hose into a piece of 4-inch gas-pipe attached to the upper side of the tube and was divided by a fork, through the recurved legs of which it passed into nozzles inserted in the sides of the tube and pointing toward its upper end, inducing a current which raised to the surface the material stirred up by the jet.

The excavator was located about 500 feet from the Missouri shore just below the dike, on which the water was about 3 feet deep. The dredge as arranged was found to work well until the excavation had been carried to a depth of about 15 feet, when the upper end of the tube choked with sand. At a depth of about 10 feet soundings showed that sand was raised at a rate of about 1,000 cubic feet per hour. This rate, however, varied greatly with the depth. It was evident that more pressure was needed in the inducing jets, and the whole power of the pump was applied to them. The velocity of the discharge through the tube was thus greatly increased, stones of three or four pounds' weight being brought up through the tube from a depth of 15 feet, but the flow of sediment was very irregular, showing the necessity of a stirring-up jet. This was supplied by the jet of pile driver No. 3, which was anchored along side. With this arrangement excavation was carried to a depth of 27 feet. Brush found at a depth of over 20 feet located the foundation mattress of the dam, which was undermined to a distance of about 15 feet, when progress was interrupted by the falling of brush and stone into the excavation, this material, however, falling from the downstream edge of the dam without lowering its crest, which was 40 feet wide at this place.

Operations were suspended September 22, on account of the breaking of a hand-hole plate in the boiler of the excavator. A clump of piles was driven through the dike about 150 feet from the Missouri shore, just inside the best steamboat channel. This clump was used as a Government light-house.

The river continued falling, and soundings taken on the 3d of October showed but 4 feet of water in the available channel over the dam.

The work of cutting a channel through the dam by dredging was begun October 12, by the contractors, H. S. Brown & Co., of Quincy, Ill., under their proposal of October 7. Their dredge was located about 400 feet from the Missouri shore and moved in toward the bank as the dam was removed. Dredging was continued until November 9, when a channel had been excavated 385 feet wide, beginning about 15 feet from the Missouri shore. This channel had a minimum depth of 9½ feet when the gauge at Alton read 8 feet above low water. The channel was used by steamers during the balance of the low-water season, and although the river fell considerably after work was finished, no complaints were made of this locality, and it does not seem probable that more work will be required at this point.

The minimum thickness of the layer of stone removed was 4 feet, but as some of the rocks dredged up were from 2 to 4 feet long and nearly as wide and thick, this depth was exceeded in places.

The total quantity of material removed, calculated by surface measurement, was 2,451 cubic yards, of which about 25 per cent. was stone; 127.6 cubic yards of this stone was unloaded upon the dike at Alton Harbor, the remainder was dumped in the deep hole under the shore end of the dam.

A considerable quantity of brush was dredged up from the foot-mat. It was found in a very good state of preservation after being submerged for six years.

The material excavated was measured and the work inspected by Mr. Gerald Bagnall, who displayed the same energy and ability in this as in all other duties assigned him.

Very respectfully, your obedient servant,

C. D. LAMB,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

12.

ALTON HARBOR.

REPORT OF MR. C. D. LAMB, ASSISTANT ENGINEER.

SAINT LOUIS, MO., *July* 16, 1883.

MAJOR: I have the honor to submit the following report of operations at Alton Harbor during the fiscal year ending June 30, 1883.

In accordance with your letter of instructions, dated August 31, 1882, operations for improving Alton Harbor were resumed on the 4th of September.

The changes progressing in the harbor during the spring continued through the summer; the large bar at the foot of the levee moved steadily down-stream, and the scour above the dike was very marked, amounting to about 6 feet since work was begun. This scour also extended for some distance below and inside the down-stream end of the dike. The material removed seems to have been deposited in front of the tow-head below, forming a reef which is continually moving down-stream and crossing the main channel of the river against the large bar below. There had been a very marked fill below the dike, especially near the Missouri shore, where it amounted to about 12 feet.

The work done during the spring was found in good condition. The crest of the dike was from 8 to 12 feet above low water, and as the surface of the river was but 9 feet above the same plane, there was little water running over the dike, except through a few narrow depressions near shore.

The ways were found in good condition, and the construction of mattresses was begun on the 6th of September, which was as soon as a supply of brush could be procured, and continued until the 17th of November, when sixty-one mattresses had been constructed and placed. One of these mats built in position was 420 feet long, two others 100 feet each, and the remainder were each 80 feet long, all being 42 feet wide and 2½ feet thick.

These mattresses raised the dike between the points A and B to a height of about 10 feet above low water. Owing to the continued low stage of river, the method of building the dike above that height was changed by your verbal instructions, 10 feet above low water being fixed as the height of the mattress work; the dike above that stage to be built of riprap. Most of the stone received while mattresses were being built was expended in sinking them, but after the mattress work was finished the stone work progressed very rapidly, and the dike had been completed to a distance of 3,000 feet from its upper end December 7, when work was suspended on account of cold weather and running ice.

The equipment was temporarily laid up in Alton Slough until December 13, when the river became clear of ice and the stone remaining on the barges was towed to the dike and unloaded. This stone was sufficient to complete the dike for a distance of 500 feet further, but as the river had fallen about 5 feet since work was suspended, the loaded barges could not be landed within 800 feet of the lower end of the completed part. The stone was therefore placed as evenly as possible over the dike, between 3,800 feet and 4,500 feet from its upper end, raising that portion to a height of about 12 feet above low water. Four of the barges were then towed to Saint Louis, and the remainder left in the slough until December 31, when they were also towed to Saint Louis by the steamer A. A. Humphreys.

The appropriation being exhausted, no work was done at this place during the last half-year. The changes in the condition of the harbor have been continuous throughout the year; the depths at the lower part of the levee have increased from 3 to 6 feet, and the channel is much nearer shore at that place. The reef, which at the beginning of the year was opposite the water-works, has moved down below the head of Ellis Island, a distance of about 1,200 feet, crowding the channel down against

the edge of the large bar below. When work was suspended in December a strong current was running around the head of the dike into the slough, and the head of Ellis Island was being rapidly cut away by the water running through the narrow passage between it and the tow-head above, but the old dam behind Ellis Island, which is now being raised to a height of 15 feet above low water by private parties, will prevent any considerable quantity of water from passing down on the Missouri side of the island. The present condition of the harbor is shown by the accompanying tracing, Plate I.

The mattresses were built of the same size and in the same way as during previous seasons. Larger mattresses could have been handled by the boat with safety, but as, owing to the low stage of water, only about 250 cubic yards of stone could be towed to the work on each barge, and as this quantity was just sufficient to sink two mattresses, each 80 feet long, they were nearly all made of that length. The bottom tier was built as one continuous mattress for a distance of 490 feet, beginning 2,368 feet from shore. The water was but a few inches deep at this point, and the mat was built in position, the wires being attached to the bottom grillage poles before the brush was put on. The ends of the wires were held above the brush by attaching them to pegs thrust into the sand. Three other mats were afterwards built in position to close depressions in the crest of the brush work. The layer of stone used to complete the dike is 4 feet wide on top, from 15 to 20 feet wide at its base, and varies in thickness from 4 to 6 feet, being what was required to raise the top of the dike to the height of 14 feet above low water. The quantity of stone required for this purpose was considerably increased by the settling of the mattresses, which amounted to over a foot on that portion of the dike constructed during the previous year.

A section of the dike, as actually constructed, is shown in Plate —.* The shape and extent of the work done during the season is indicated by Plate —,* the mattresses placed in previous seasons being shown by red numbers. Referring to this plate, it will be seen that eight mattresses were used to fill depressions in the 2,200 linear feet of dike constructed during the previous season. Twenty-seven mattresses, each 80 feet long, and one 490 feet long, were used in extending the bottom tier to the point B. The remaining twenty-five mattresses were placed on the second tier. The top of the mattress-work was thus raised to a nearly uniform stage of 10 feet, except toward the lower end of the line, where it is about 8 feet above low water.

The brush used was procured by hired labor from Mobile Island and from the tow-head in the harbor. The larger part of the stone was procured from the Grafton Quarry Company, being loaded upon Government barges at Grafton. Owing to the scarcity of labor and other causes, only about 800 cubic yards per week were furnished. This was about the rate at which it was required for sinking mattresses, and no progress could be made in facing the top of the dike. Efforts were made early in the season to procure an additional supply of stone, but without success.

When the cutting of the brush was discontinued the force and equipment thus employed was transferred to Grafton, and the loading of stone begun from the shore below the quarry; 650 cubic yards were procured at this place, on which no royalty was paid. The force was then removed to the Illinois shore, near the foot of Piasa Island, where it remained until it was disbanded December 7, 1,550 cubic yards having been loaded, at a cost of 60 cents per yard, including a royalty of 10 cents per yard.

It was found that stone, when broken up and piled within wheeling distance of the barge, could be loaded at a cost of about 18 cents per yard.

A proposal was received from the Missouri Stone Company, and four barges were loaded at their quarry near Hop Hollow. This company can furnish stone as low as 60 cents per yard, but should other work be done in this vicinity a quarry might be leased, and stone loaded by hired labor for less than that amount.

The piling used was cut on Piasa Island and rafted to the work. The other material used was purchased in Saint Louis.

The following statement shows the amount of work done during the year and its cost:

To labor constructing and sinking 5,300 linear feet or 21,200 cubic yards of mattress		$7,379 29
To 4,534 cords brush	$7,128 26	
To 72 sticks, 1,960 feet piling	221 75	
To 138,174 cubic yards stone	14,022 65	
To 6,000 pounds wire	270 00	
		21,642 66
To equipment, steamer Little Eagle No. 2	2,449 53	
To equipment, pile-drivers	67 20	
To equipment, skiffs	364 58	
To equipment, tools	551 57	
		3,432 88

* Plates not forwarded.

Engineering and contingencies:

To engineering	$1,230 32	
To contingencies	314 85	
		$1,545 17
Total		34,000 00

The number of cubic yards of brush and stone placed in the dike during the year was about 35,000, at a cost of about 97 cents per yard. About 58,700 yards of dike have been constructed since the work was begun, at a cost of $67,324.70, or $1.15 per yard.

This average is increased by the cost of the work done during the fall of 1881, which was $2.90 per yard, as only 3,500 cubic yards were built on account of bad weather and rapid changes in the stage of the river.

Very respectfully, your obedient servant,

C. D. LAMB,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

13.

SUPPLY DEPOT.

REPORT OF MR. C. L. STEVENSON, SUPPLY CLERK.

UNITED STATES ENGINEER DEPOT,
Saint Louis, Mo., June 30, 1883.

SIR: I have the honor, respectfully, to submit a report of the operations at this depot for the fiscal year ending June 30, 1883.

The equipment was increased by the construction of two hulls for pile-drivers, nineteen hurdling flats, one floating machine-shop, one wharf-boat, three second-hand coal barges, converted into barge flats for carrying material, four portable shanties for telephone offices, one half section of portable shanty, three foreman's quarters, six complete sets of portable shanties for quarters.

The materials which were prepared and framed for building two new hulls for the machinery of pile-drivers No. 3 and 5 in the first half of 1882 were put together, the machinery (thoroughly repaired) was adjusted on the new hulls, and the drivers were transferred for service, No. 3 on the 6th of September, and No. 5 about the 11th of October.

The hulls are substantially built of good material, according to the general designs of those previously made here and described. The new are 7 feet longer and 2 feet broader, and the cabins 4 feet longer and 1 foot wider than the old ones, making hulls 20 feet wide, 67 feet long, 3 feet hold; cabin, 13 feet wide, 34 feet long, 8 feet high.

The dimensions of the hurdling flats are of 12, 10 feet broad, 35 feet long, 24 inches deep; of 7, 9½ feet broad, 35 feet long, 22 inches deep.

They were built, from time to time, in the first half year as they were needed, are strongly made, fastened and braced with iron.

Two of the former are decked and furnished with a boom derrick, with stiff guys, for use in constructing hurdles.

The gunwales of twenty-seven large flats were raised 6 inches, making them 22 inches deep.

To facilitate repairs to machinery by avoiding delay attending its transfer to the depot, the old hull of pile-driver No. 5 was repaired and strengthened, a cabin 14½ feet wide, 49½ feet long, 8 feet ceiling built thereon and used as a floating, movable, machine shop. It was supplied with the equipments, tools, &c., requisite for such work, and put into service about the 21st of October.

To afford easy shipment of freight, and a suitable protection to supplies intransitu in very low water—the platform of the wharf being inaccessible with ordinary means at that stage—the old hull of pile-driver No. 3 was repaired and strengthened, a cabin 17 feet broad, 48 feet long, and 8 feet ceiling built on it to be used as a wharf-boat. It was completed for service about the 16th of September.

Barge flats Nos. 41, 46, and 51 were converted into temporary mattress barges by constructing thereon platforms and ways. The platforms, similar to those on the regular mattress barges, extend 4 feet over the upper side. The ways are of oak, those of No. 41 extending 14 feet and the other two 15½ feet over the lower side to within 2 feet of the water, and are of sufficient length to weave a mattress 100 feet broad.

Ways for making narrow mattresses were built on eighteen large flats.

A new platform, 120 feet broad, extending 3½ feet over the upper side, was placed under the ways on mattress barge No. 2.

Three second-hand coal barges purchased to be altered for carrying materials were strengthened, the additions, finishing, &c., being similar to those now in use, which have been definitely described heretofore. They were fitted out each with new pumps, capstans, head and stern lines, marked United States Engineer Department, "No. 57," "58," and "59," respectively, and transferred to service Nos. 57 and 58, July 29, and No. 59, August 19.

Four portable shanties, each 12 feet long, 10 feet broad, and 8-foot ceiling, were made; three were transferred and put up, one at each of the following named places, viz, Meramec, White-house, and Ivory Station, on the Iron Mountain Railroad, for use as telephone offices for the works at Jim Smith's and Chesley Island, at Beard's Island, and at Horsetail, respectively. The fourth is here, subject to requisition.

One half section, 7½ feet long, 20 broad, and 8-foot ceiling, for sleeping quarters, was added to those on barge flat No. 28.

Three portable shanties, each 20 feet broad, 30 feet long, and 8-foot ceiling, were made and transferred to works, 2½ sections to Foster's Island, and one-half section to Chesley Island, to be put up there as foreman's quarters.

Agreeably to orders from headquarters, received about the 1st November, to construct six complete sets of portable shanties to be used as quarters in the next season, they were commenced at once, and, with their complement of furniture, were completed about the 1st of February. Each set is composed of one mess-room and kitchen, 20 feet broad, 60 feet long, 8-foot ceiling, with suitable divisions for store-room, pantry, and sleeping quarters for boarding master, cook, and waiters. One sleeping quarters, 45 feet long, and one foreman's quarters, 30 feet long, with other dimensions same as the mess-room and kitchen. Each set makes a complete outfit for seventy-two laborers, with complement of overseers and attendants.

These shanties are made in sections easily handled and put together, each set, with 306 carriage bolts. A description of similar ones, the manner of putting them together, have been described in previous reports.

One set of the sleeping and one set of the foreman's were put up on barge flat No. 48, to be used as quarters. One set of the foreman's and one section of another foreman's quarters were added to those on quarter barge No. 31.

To shut off the depot grounds from the public thoroughfare along the Iron Mountain Railroad, a board fence, 6 feet high and 521 feet long, was put up, which, connecting with the storehouses, extends from the old arsenal wall on the north to that on the south side of the depot. This line, the two walls, and the river inclose the ground occupied by the Engineer Department.

Among the smaller constructions are one hundred and seventy-eight benches, one hundred and fifty-six bunks, sixty-seven tables, ten trestles, eighteen thousand four hundred bolts, assorted; two thousand four hundred and forty-five pile stirrups, assorted sizes, and a large number of implements, tools, and appliances.

REPAIRS

which were made are described as follows, viz:

Steamer Humphreys.—In the first half of the year the wood work on the wheel was renewed, a new ice-box for transportation of perishable provisions added, a bulkhead was made to the after part of the boiler to retain heat, hold was braced on both sides, which had been damaged by ice; stanchions, steps, and boiler deck-rail repaired. In March she was drawn onto the ways, her hull overhauled, a sheet of iron plating renewed on both sides of her bow, an iron shoe put on the stern, new rivets added where needed, rudder irons repaired, plates of iron were placed under the outrigger—one on each side—to stiffen the guards, in place of old ones, which were of wood; gallows-frame knees repaired, bed-plate for capstan spindle renewed. She was calked around the stern-post, and her hull painted. The nigger engine was removed from the hold, placed and adjusted on deck.

Steamer General Gillmore.—The machinery for furnishing her with electric light was fixed in position.

Steamer Anita.—Stern-post repaired in the first half of the year. During the winter her machinery was removed to the hull of the new steamer General Gillmore, and the old hull is here, being used for the present as a wharf-boat.

Launch Florence.—Purchased to be used as a tender to the engineer working parties, was raised from the water, her hull and machinery overhauled, thoroughly repaired, and hull painted. Later in the season she was again taken out, leaks in siphon and mud-pump stopped, machinery again overhauled and repaired, and a new propeller wheel, a roof, pilot-house and pilot-wheel added.

Launch Hornet.—The cabin, pilot-house, pilot-wheel, and forward deck, which were burned, were replaced by new ones. Subsequently a new rudder was made and fitted, skeg and other parts of her hull repaired.

Hydraulic excavator.—A boom derrick, crab frame, and davit were made and fitted. To increase the current of the water in the sand pump two goose-neck copper pipes were fitted, and protected under water by a basket-work of iron.

Pile-drivers.—A new set of leads and braces and one lead, one brace, and one wench-post were added, the former to No. 19 and latter to No. 21.

Slight repairs, calking, &c., were made to Nos. 1, 9, 10, and 17.

The floating machine shop was transferred to the depot on the 11th of April, since which time the machinist has been engaged in overhauling and repairing machinery to pile-drivers.

Drivers Nos. 1, 3, 6, 7, 8, 15, and 18 have been put in thorough repair. These drivers, except No. 3, are furnished with Worthington pumps, in which were used brass packing. These were found to cut easily in muddy water; to be, therefore, defective and expensive, and the pumps were altered by our machinist so as to use other less expensive and more useful packing—a description of which I will give in his words, viz:

"In working the Worthington pump it was found necessary to substitute some other packing for that used to secure at all times a full valuation of her working capacity. The original packing (a brass ring fitting the plunger and held by a gland stationary in the center of the pump, the plunger traveling through same) in pumping muddy water would cut and enlarge ring so that churning of water would occur, necessitating new rings in order to secure valuation of pump.

"Our manner of substitution is to bore out the middle partition where the original brass ring was held, fitting it in a stuffing-box and gland, the box having four turns of five-eighths inch square elastic packing. When churning commences with this packing the heads of the water-ends of the pump must be taken off and gland screwed up; not over fifteen minutes' work.

"The elasticity of the filling insures a tight packing.

"One filling will be sufficient for a pump an entire season, doing full work, at a cost of about $1.20—3 pounds of rubber and canvas.

"The stuffing-boxes and glands will outlast the pump.

"No. 10 driver—the first to which the improvement was applied—after being used about three months was subjected to a test of water pressure of 179 pounds to the square inch (one-third more than it was calculated to bear), and on examination of the packing it was found to be in perfect shape, thus proving the substitution to be what our service requires, a simple, easily adjusted, and inexpensive packing, comprehensive to any one.

"Since the 11th of April we have put new stuffing-boxes and glands in drivers Nos. 1, 6, 7, 8, 9, 10, 13, 15, and 18."

Barges.—The bitts, timber-heads, kevils, capstan-bed, deck, and sheathing of No. 9 were repaired, and her top sides calked all around.

Four new timber-heads, four braces, and five cross-chains were added to No. 46, her hull repaired and calked.

Four pieces of gunwales and two planks on the rake on one side, and two pieces of gunwales, one stiffener, and three rake planks on the other side of No. 53 were renewed, hull repaired and calked.

Nos. 12, 23, 32, 49, and 51 were placed in dry-dock and thoroughly repaired.

Slight repairs were made to Nos. 14, 17, 25, 27, 28, 33, 34, 38, 40, 42, 54, 57, 58, and 59.

The pumps and bitts of No. 10 were repaired, top sides, calked all around, and hull painted.

The bow of No. 13 was raised from the water with side dock, a plank below water line cut by the ice was replaced by a new one, her hull calked and painted.

Bitts, capstan-bed, deck, and hatches of No. 16 repaired, her hull calked and painted.

The pumps of No. 20 were repaired and hull painted.

The top sides of Nos. 22 and 26 were calked all around and hull painted.

Mattress-barges.—That part of the ways extending over the sides of No. 3 were repaired.

Quarter-boats.—Slight repairs were made to Nos. 2, 4, and 6. The canvas renewed in several places on the roof of Nos. 4 and 6, and roof painted.

Wharf-boat.—Slight repairs made twice during the year.

Small boats.—Yawls, skiffs, large and small flats have been overhauled, repairs made where needed. Those in service repainted, such as are not needed at present put under cover, and all re-marked "United States Engineer Department," with their individual numbers in the respective series.

The private telephone of the Engineer Department, which puts the depot in communication with headquarters and the several engineer parties, and the city wires which connect it with the machine shops and the material and supply market in the city, have greatly facilitated operations here by enabling us to meet the wants at the works without the delay incident to ordinary means of communication.

* * * * * * *

With much respect, your obedient servant,

C. L. STEVENSON,
Supply Clerk.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

14.

SUBSISTENCE.

REPORT OF MR. S. S. VAN NORMAN, SUBSISTENCE CLERK.

UNITED STATES ENGINEER DEPOT,
Saint Louis, July 7, 1883.

MAJOR: I have the honor to submit my report of operations in the subsistence department connected with the works of improvement under your charge, for the fiscal year ending June 30, 1883.

The present system of providing for employés under your direction was first introduced in March, 1882, and as I believe it embraces features now to many engaged on works of public improvement where large bodies of men have to be cared for, this report is made to include the time from the adoption of the system up to the end of the fiscal year.

ORGANIZATION.

(1) *Subsistence clerk.*—The subsistence clerk has special charge of the procurement and issue of subsistence supplies at Saint Louis, and regulates the bill of fare according to the season.

He also acts as special inspector of boarding masters, and visits, from time to time, the boarding houses, inspecting the boarding master's subsistence records, and the manner in which they perform their duties, reporting the result of his inspection to the officer in charge.

(2). *Boarding masters, cooks, and waiters.*—For each kitchen there is employed one boarding master at a compensation of $60 per month, one cook at $50, and one cook at $30, with attendants in the proportion of one for every eighteen men provided for; the compensation of attendants being $20 per month; all of these persons being provided with subsistence in addition to the above salaries.

The boarding masters are responsible, under the direction of the resident engineers, for the proper preparation and service of the food, for the timely procurement of supplies, for the good order and cleanliness of the sleeping quarters, mess-rooms, and kitchens, and for the preservation of the bedding, furniture, and subsistence stores.

QUARTERS.

Portable quarters, placed upon barges or on the shore, are provided, each set of which will accommodate seventy-two men and their attendants with kitchen, mess-room, and sleeping quarters.

Allowance of mess furniture for one mess-room accommodating seventy-two men.

Articles.	Quantity.	Remarks.
	Number.	
Basins, wash	12	
Bowls, sugar	8	
Boxes:		
Pepper	12	
Mustard	12	
Brushes:		
Scrub	4	
Dust	2	
Cellars, salt	12	
Cruets, vinegar	12	
Cups, coffee	72	
Dishes:		
Butter	8	
Gravy	8	
Vegetables	16	
Dippers, tin	4	One-pint.
Forks, table	72	
Knives, table	72	
Pitchers:		
Milk	8	
Molasses	6	
Water	4	One-gallon.
Plates:		
Dinner	80	
Soup	72	
Saucers	144	Extra saucers used for side dishes.
Spoons:		
Table	96	
Tea	80	
Towels, roller	24	Three yards each.
Tumblers	72	

Allowance of furniture for one kitchen accommodating seventy-two men.

Articles.	Quantity.	Remarks.
	Number.	
Ax	1	
Basin, wash	1	
Barrels, water	2	
Beater, egg	1	
Boiler:		
Wash	1	Twenty-gallon galvanized iron, with cover.
Soup	1	
Coffee	1	Twelve-gallon, with strainer and faucet.
Tea	1	Eight-gallon, with strainer and faucet.
Board:		
Wash	1	
Chopping	1	1 foot by 2 feet by 2 inches.
Molding	1	3 feet by 3 feet, with 4-inch sides and back.
Box, dredge	1	
Brooms	2	
Brushes:		
Scrub	2	
Dust	1	
Buckets, water	6	
Can, milk	1	Four-gallon.
Cleaver:		
Butcher	1	
Light	2	For chopping meat fine.
Clock, marine	1	
Cups, tin	6	
Cullenders	2	
Forks:		
Carving	2	Large.
Meat	2	Do.
Grater, bread	1	
Grater, nutmeg	1	
Griddle	1	
Hatchet	1	
Hook, ice	1	
Jars	2	Five-gallon.
Kettles:		
Camp	4	Heating water for men's washing.
Sauce	2	
Knives:		
Carving	1	10-inch.
Butcher	2	One, 8-inch; one, 12-inch.
Pallett	1	10 inches.
Mashers, potato	2	
Mill, coffee	1	
Mop	1	
Opener, can	1	
Pans:		
Bread	2	
Baking	5	
Frying	1	
Pin, rolling	1	
Plates, pie	18	
Poker, iron	1	
Pots:		
Coffee	4	One-half gallon.
Tea	4	Do.
Saw:		
Wood and buck	1	
Meat	1	24-inch.
Scales:		
Beam	1	500-pound.
Spring	1	
Scoops, tin	4	Assorted sizes.
Shovel, fire	1	
Shovel, coal	1	
Sieve, flour	1	
Skimmer	1	
Spoons, kitchen	6	Iron.
Steel, knife	1	10-inch.
Stove, cook	1	Coal, hotel superior No. 9.
Towels:		
Dish	6	One yard each.
Hand	4	Ordinary crash.
Tubs, wash	3	

Allowance of bedding for seventy-two men.

Articles.	Quantity.	Remarks.
Blankets, double..... pairs..	36	
Comforts..... number..	36	
Cases, bolster..... do....	36	
Sacks, bed, double..... do ...	36	
Sheets, double..... do....	72	
Slips, bolsters..... do....	36	

Two men occupy one bunk. Straw is provided for filling the bed-sacks and bolster-cases.

Single bunks are provided for the overseers, who are also allowed moss pillows in place of bolster-cases.

Resident engineers are furnished with a cot, mattress, and feather pillow each, besides the necessary allowance of blankets, sheets, and pillow-slips.

SUBSISTENCE STOREHOUSE.

This building is located at the engineer supply depot, foot of Arsenal street, about 3 miles from the central portion of the city. It is a frame structure, 25 feet wide by 125 feet long, with a cellar of the same dimensions.

The building will easily hold two months' supplies for 2,000 men.

PROCUREMENT OF SUPPLIES.

When stores are required the subsistence clerk procures proposals from the principal dealers, accompanied by samples, and then makes requisition upon the officer in charge for the articles, forwarding at the same time the proposals, with an abstract thereof, and a recommendation as to which one should be accepted.

The above applies to all subsistence stores, except fresh vegetables, which are purchased in open market, as required.

At least one month's supply of non-perishable stores is kept on hand in the subsistence storehouse.

DISTRIBUTION OF SUPPLIES.

Fresh meat and vegetables are issued semi-weekly; potatoes, flour, and butter weekly; and other supplies semi-monthly.

Requisitions from each boarding master are sent direct to the subsistence clerk three days in advance of the time the stores are required.

Invoices and receipts accompany each lot of supplies sent out.

Resident engineers sign receipts for stores received by each boarding master under their charge, and return them direct to the subsistence clerk. In addition to these duplicate receipts are made, one of which is signed by the mate of the boat on which the supplies are shipped and returned to the subsistence clerk; the other is signed by the boarding master receiving the stores and returned to the mate, who holds it as his voucher.

QUALITY OF SUPPLIES.

The quality of supplies furnished may be termed "choice." Flour is required to grade choice, and other farinaceous foods are the best the market affords.

Cured meats are of the best quality, and fresh meats the best to be had without specifying "stall-fed."

The following list of supplies provided gives detailed information as to variety and quality:

Articles.	Quality.
Apples, dried.....	Choice.
Allspice.....	Clean sifted.
Bacon, breakfast.....	Choice.
Beef.....	Best mess.
Beans.....	Choice navy.
Butter.....	Choice dairy.
Coffee.....	Prime Rio.
Crackers.....	3 X Soda boxes.
Cheese.....	Full cream.
Codfish.....	Summer cured.

Articles.	Quality.
Extract:	
Lemon	Price's full pints.
Vanilla	Do.
Flour, wheat	Choice, inspected.
Grits	Choice and fresh in barrels.
Ginger	Pure ground, one-quarter pound packages.
Hominy	Choice and fresh in barrels.
Lard	Choice kettle-rendered, 20-pound buckets.
Lye	Concentrated, Pitts', four dozen in case.
Meal:	
Corn	Choice kiln dried, in barrels.
Oat	Choice, coarse, 2-pound packages.
Macaroni	Domestic, 10-pound boxes.
Mustard	Burrows' Lexington, half-pound tins.
Molasses, S. H	Belcher's.
Mackerel, No. 1	Half barrels, 100 pounds net.
Milk, condensed	Eagle brand.
Nutmegs	Prime sound.
Onions	Choice, dry.
Powders, yeast	Price's, 6-pound tins.
Pepper	Pure, ground, half-pound tins.
Pickles	Medium, plain, 5-gallon kegs.
Peaches, dried	Choice, halves.
Potatoes	Choice quality.
Pork	Choice mess, 200-pound barrels net.
Rice	S. C. choice and fresh.
Raisins	Loose muscatel.
Sugar	Belcher's Standard C.
Salt	Dairy, 10-pound bags.
Salt	Lake, 280-pound barrels.
Sauce, pepper	Half-pint bottles.
Soap	Best extra family.
Shoulders	Plain, cured.
Soda, sal	
Tea, oolong	Good medium, half chests.
Tomatoes	Choice, gallon cans.
Vinegar	Cider, forty grains.

In addition to the above, about thirteen different kinds of fresh vegetables are furnished in season.

COST OF SUBSISTENCE.

The average daily cost per man, with the average number of men subsisted daily, is given in the following table, and includes cost of service of all persons employed in connection with subsistence:

Months.	Average number of men subsisted daily.	Average daily cost per man.
1882.		
March	531	$0 50
April	791	45½
May	969	43
June	632	50
July	657	49
August	937	43
September	1,039	42
October	1,096	42
November	1,162	47
December*	732	52
1883.		
March	281	51
April	462	42
May	382	42
June	192	40

* From 1st to 18th.

From the above it appears that while there were more than double the number of men subsisted during the first four months of 1882 than for the same time in 1883, the average daily cost per man in the first case was 47 cents, and in the latter only 44 cents.

With a full working force the cost of the ration could be still further reduced, as has been demonstrated this season. In one case 68 men were subsisted one month at a cost of 35 cents per day for each man, and again 43 men were boarded for the same time at a daily cost of 37 cents per man.

The bill of fare for each day is as follows:

Day.	Breakfast.	Dinner.	Supper.
Sunday	Coffee, bread and butter, shoulder and beefsteak, potatoes.	Soup, roast beef or pork, mashed potatoes, vegetables, coffee, pudding.	Coffee or tea, bread, and butter, meat and potatoes, stewed peaches.
Monday	Coffee, bread and butter, beefsteak, boiled potatoes.	Soup, roast pork, boiled potatoes, turnips or other vegetables, pudding.	Coffee or tea, bread and butter, beef and pork, potatoes, fried or stewed.
Tuesday	Coffee, bread and butter, meat stew, boiled potatoes.	Soup (bean or rice), roast mutton, potatoes, vegetables, pie or pudding.	Coffee or tea, bread and butter, mutton and shoulder, potatoes, oatmeal or grits.
Wednesday	Coffee, bread and butter, beefsteak, breakfast bacon or shoulder, potatoes, stewed apples.	Soup, roast beef, potatoes, tomatoes (canned or fresh), pie or pudding.	Coffee or tea, bread and butter, beef and salt meat, potatoes.
Thursday	Coffee, bread and butter, beefsteak, potatoes, fried or stewed.	Soup, mess beef and cabbage or other vegetables in season, potatoes, bread pudding.	Coffee or tea, bread and butter, beef (salt or fresh), potatoes, stewed apples.
Friday	Coffee, bread, corn-bread, butter, mackerel and beefsteak, potatoes.	Vegetable soup, codfish, potatoes, macaroni, bread or rice pudding.	Coffee or tea, bread and butter, cheese, oat-meal or grits, potatoes, stewed peaches.
Saturday	Coffee, bread and butter, beefsteak, potatoes.	Soup, salt pork and baked beans, potatoes, pudding.	Coffee or tea, bread and butter, shoulder, mush, potatoes.

The allowance of subsistence stores for one hundred men for one week, with the amounts allowed for each day, is as follows:

Articles.	Sunday.	Monday.	Tuesday.	Wednesday.	Thursday.	Friday.	Saturday.	Total.
Allspice.....pounds..	.0907	.0907	.0907	.0907	.0907	.0907	.0907	.6349
Apples, dried.....do....	6				6			12
Bacon.....do....				17				17
Beef, mess.....do....	9				35			44
Beans.....do....			23				23	46
Butter.....do....	14	9.38	9.38	9.38	9.38	9.38	9.38	70.28
Cheese.....do....						8		8
Coffee.....do....	6.631	4.42	4.42	4.42	4.42	4.42	4.42	33.151
Codfish.....do....						27		27
Crackers.....do....	7	7	7	7	7	7	7	49
Extracts.....pints..	.05	.05	.05	.05	.05	.05	.05	.35
Flour.....pounds..	79.21	79.21	79.21	79.21	79.21	79.21	79.21	554.47
Grits.....do....	as required.							
Ginger.....do....								
Lard.....do....	5.5	5.5	5.5	5.5	5.5	5.5	5.5	38.5
Macaroni.....do....		5				15		20
Mackerel.....do....						20		20
Meal, corn.....do....						11	15	26
Meal, oat.....do....	as required.							
Meats, fresh.....do....	136	136	136	136	136	41	136	857
Milk, condensed.....do....	4	4	4	4	4	4	4	28
Molasses.....gallons..	.5	.5	.5	.5	.5	.5	.5	3.5
Mustard.....pounds..	.02	.02	.02	.02	.02	.02	.02	.14
Nutmegs.....do....	.014	.014	.014	.014	.014	.014	.014	.098
Onions.....do....	8.62	8.62	8.62	8.62	8.62	8.62	8.62	60.34
Peaches, dried.....do....	7.5		7.5			7.5		22.5
Pepper, black.....do....	.25	.25	.25	.25	.25	.25	.25	1.75
Pickles.....gallons..	.42	.42	.42	.42	.42	.42	.42	2.94
Powders, yeast.....pounds..	.67	.67	.67	.67	.67	.67	.67	4.69
Potatoes.....do....	115	115	115	115	115	115	115	805

Articles.	Sunday.	Monday.	Tuesday.	Wednesday.	Thursday.	Friday.	Saturday.	Total.
Pork, mess .....pounds..	.....	.....	.....	26	.....	.....	26	52
Raisins.....do....	2.5	.....	2.5	.....	2.5	.....	.....	7.5
Rice .....do....	.....	.....	7.45	.....	.....	7.45	.....	14.9
Salt.....do....	5	5	5	5	5	5	5	35
Sauce, pepper.....bottles..	.5	.5	.5	.5	.5	.5	.5	3.5
Shoulders, smoked.....pounds..	10.58	.....	10.58	.....	.....	.....	10.58	31.74
Soap .....do....	6	6	6	6	6	6	6	42
Sugar .....do....	23	23	23	23	23	23	23	161
Tea .....do....	1	1	1	1	1	1	1	7
Tomatoes .....cans....	.67	.67	.67	.67	.67	.67	.67	4.69
Vegetables, fresh.....	As determined by subsistence clerk.							
Vinegar .....gallons..	.5	.5	.5	.5	.5	.5	.5	3.5

The above allowance was prepared from data furnished by the subsistence records for last season, and is subject to such modification as further experience may suggest.

Very respectfully, your obedient servant,

S. S. VAN NORMAN,
Subsistence Clerk.

Maj. O. H. ERNST,
U. S. Engineers.

15.

PILE-DRIVING IN SANDY SOILS.

REPORT OF LIEUTENANT FREDERIC V. ABBOT, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., April 30, 1883.

MAJOR: I have the honor to submit the following report on the subject of pile-driving, in accordance with your order of June 10, 1882, as below:

"UNITED STATES ENGINEER OFFICE,
"*Saint Louis, Mo., June* 10, 1882.

"SIR: Having reported to me in accordance with Special Orders No. 125, Headquarters of the Army, Adjutant-General's Office, Washington, D. C., May 31, 1882, you are assigned to duty in this office.

"You are specially charged with the study of pile-driving in sandy soils. It is desired that all obtainable information on the subject be obtained, in order to ascertain whether or not the machines now in use under this office can be improved upon. In pursuing your investigations, should you desire to visit other cities or localities, you will, on application, be authorized to make the necessary journeys.

"Very respectfully, your obedient servant,

"O. H. ERNST,
"*Major of Engineers.*

"First Lieut. F. V. ABBOT,
"*Corps of Engineers, U. S. A.*"

In accordance with the above order, I made a careful search for information on the subject; the matter in print was very slight, and what was stated was very general and unsatisfactory in its nature.

To carry out the provisions of your order it was plainly necessary to make a thorough study of the drivers under your orders, but the high stage of the Mississippi River prevented them from working under normal conditions till the middle of July.

On the 21st of that month I took up my residence at Jim Smith's, and watched the action of your drivers there at work.

The following scheme of observations was adopted at the start and continued throughout:

I took position on the roof of a pile-driver, and recorded the time at which each operation was begun and completed. The record was kept with great care, and included all epochs which were distinctly enough marked to admit of observation.

I continued these observations at different times, different stages of river, and at different places, throughout the summer and fall, till I had a sufficient number to give with considerable accuracy the relation between the different observed times. Care was exercised to insure an average result by observing in both easy and difficult situations.

In November I visited Chicago, pursuant to the above instructions, and made a similar set of observations on some drivers at work under the Illinois Central Railroad.

In accordance with verbal orders given me in the latter part of June, I have studied the probable advantages of placing more than one set of leads on a single flat, and a project for such a machine is herewith submitted.

I shall divide this report into five distinct heads.

First. The discussion and description of the action of your drivers in their present form, with suggestions upon the organization of the *personnel* to make it more efficient; also suggestions of small changes in the fittings, to render the present form of drivers more convenient.

Second. A discussion and description of the action of the form of pile-driver known as the "steam-hammer driver," employed by the Illinois Central Railroad, and a comparison of its efficiency with that of the jet drivers used by the same company, doing identical work.

Third. A consideration of the possible economy of using steam-hammer drivers in your works in place of the present form of jet drivers.

Fourth. A study of the law of variation in resistance offered to the penetration of a pile driven by a jet driver at different depths, as shown by some observations incidentally made last season.

Fifth. A project for a multiple lead driver, with discussion of the changes made in the form of leads, &c., and a consideration of the probable economy of constructing one.

PART I.—ACTION OF THE DRIVERS USED IN THE IMPROVEMENT OF THE MISSISSIPPI, BETWEEN THE ILLINOIS AND OHIO RIVERS.

MATERIAL.

Hull.—Figure 1, Plate —,* gives a general idea of these pile-drivers. The hull is 20 feet wide by about 64 feet long, and is made very stiff and rigid by two heavy, solid-built, longitudinal bulkheads; the leads are made of timbers 36 feet long, with iron on the faces worn by the hammer. The clear space between them is 20 inches. The hammer is of the usual form and weighs a ton.

Machinery.—The water for the jet is supplied by a No. 5 Worthington duplex pump, capable of discharging 165 gallons a minute, with a piston velocity of 100 feet a minute. By this pump the water is forced through a 2½-inch gas-pipe, *m*, *m*, *m*, *m* in the figure. This so-called *stand-pipe* terminates a few feet above the second platform in the leads, where it is coupled to a 2½ inch five-ply hose capable of supporting a pressure of 120 pounds to the square inch. This is in turn coupled to a piece of 1½-inch gas-pipe *n*, *n*, *n*, the lower end of which is connected with a piece of 1-inch gas-pipe 2½ feet long (*q*), which forms the nozzle. The reducer which connects the last two pipes is made with a square shoulder to rest on a staple driven into the pile 2 feet from its large end (the lower end), as is shown in Figures 1 and 2, Plate —.* When not in use the jet pipe stands with the nozzle resting on deck, near the leader timbers.

The hammer is permanently made fast to its line, which passes over a 15-inch sheave at the top of the leads to the drum *o*, to which it is also permanently attached. This drum (Figure 1, Plate —*) and the male friction *b* are free to slide longitudinally on the shaft *a a*; the drum also turns freely on this shaft; the male friction *b* cannot. The other male friction is permanently fast to the shaft, and is bolted to the spur-wheel *g*. The lever *c* is connected with *b* by a clutch, which allows *b* to turn with the shaft *a a*.

The action is as follows: The lever-handle *h* is nominally as far to the left (facing the leads) as it will go. In this position the drum is loose on the shaft, and the engine runs without affecting the hammer; to raise the latter, *h* is pressed strongly to the right, which forces male *b* into the female friction on that end of the drum, and slides *b* and *o* on the shaft till male *f* is pressed tightly into its female friction. The drum, being thus clamped at both ends by males turning with the shaft, must turn itself; it winds up the hammer line and raises the hammer.

When the latter is high enough *h* is moved to the left, the male frictions are thus withdrawn, the drum is freed from the shaft, the weight of the hammer uncoils the rope wound upon *o*, and strikes the pile nearly as heavily as if the fall was free, the only lessening of the blow being due to stiffness of cordage and the slight friction of the drum as it revolves on its shaft. This method leaves the height of fall and frequency of blow perfectly under the control of the master driver.

* Plate not forwarded.

The engine, a regular No. 5 Nagel agricultural engine, fifteen nominal horse-power, 12-inch stroke, 8-inch diameter of cylinder, mounted on the top of a fifteen horse-power horizontal agricultural boiler, is connected with the crab just described by a 9-inch rubber belt.

The male and female frictions are all of cast iron, and have given some trouble from wearing.

The remainder of the outfit is of the usual character, and requires no description. The anchors vary in weight from 150 to 250 pounds.

PERSONNEL.

The regular pile-driver crew is composed of:
One master driver, at $60 a month and board.
One engineer, at $60 a month and board.
Six deck hands, at 9 cents an hour and board.
Their duties are as follows:

1. *Master driver.*—The master driver is in charge of the entire crew, and is responsible for all the Government property on the driver. He manipulates the friction which raises the hammer, handles the log-chain line when the pile is raised from the water to be put in the leads, directs the engineer when to start and stop the pump and engine, keeps the time of his crew, keeps a record of piles driven and of the time lost in waiting for a supply of piles, and superintends placing the driver in position to drive each pile. He does this by sighting through the space between the leads, and directing the deck hands to strain or loosen the lines holding the flat till his eye is on a line with the two range flags, and is at the same instant at the proper distance from the last pile driven. Plate I shows the disposition of lines usually adopted.

2. *Engineer.*—The engineer attends to the firing of the boiler, keeps the steam at the proper pressure, runs the engine and pump, and keeps the machinery oiled and in good repair.

3. *Deck crew.*—For convenience, number these men 1, 2, 3, 4, 5, 6. While there is a difference with master drivers in the distribution of the work for the deck hands, the following is that adopted by the best masters.

Nos. 1 and 2.—These men are selected as being good axmen and handy with lines. They move the flat, cut the pile to the proper length, if it is not so already, sharpen it when driving in hard bottom, or in any case if the butt is more than 16 inches in diameter, and do most of the work on deck. No. 2 drives the staple which holds the jet pipe near the bottom of the pile, and he and No. 1 guide the nozzle into this staple when the pipe is raised by the crew.

Nos. 3 and 4.—These men are on the first platform in the leads. They attend the toggle at their level, assist in raising the jet pipe, and with the assistance of 5 and 6 get the pile made fast in the leads, after it is raised by the master driver.

Nos. 5 and 6.—These men are on the platform above 3 and 4, and perform similar duties. In addition No. 5 frees the jet hose from kinks, and No. 6 removes and replaces the toggle which supports the hammer when aloft.

DETAILED DESCRIPTION OF THE OPERATION OF DRIVING A PILE.

Assume that a pile has just been driven, and the hammer raised to its position of rest aloft.

A temporary line is passed round the pile at *b* (see Plate —),* to hold the flat while the two bow-lines which were on pile *a* are transferred to pile *b* by Nos. 1 and 2. When this transfer has been made, the temporary line (shown dotted) is thrown off, and the flat allowed to drift down-stream about 2 feet. It is now free from pile *b* and is held entirely by lines *c* and *d*; *c* is strained, and *d* slacked off till *b* is opposite the part of the flat occupied by *a* in Plate I. Both are now equally strained till the flat can be drawn up-stream no farther by this means. The final delicate adjustment of position is now made by the stern-anchor lines, which have the leverage of the entire length of the flat and thus allow a very gradual and accurate change of the position of the center of the leads, which moves on the arc of a circle whose center is at *a* in the sketch.

While 1 and 2, under the direction of the master driver are thus at work, the rest of the crew have hauled a pile from the rear of the flat, at *e*, to a position near *f*. Here the "log-chain line" is passed round the small end of the pile (this end is up-stream), and is shifted toward the butt till it holds the pile at a point a few feet on the *small end* side of the center of gravity. With a well-drilled crew, this is all accomplished by the time 1 and 2 have the flat in place.

As soon as the flat is properly in position the master driver takes several turns with

* Plate not forwarded.

the log-chain line round the winch-heads at *k*, and directs the engineer to start the engine. This line, passing over a sheave at the very top of the leads, raises the pile out of the water till it hangs, *small end up*, in front of the leads. If the pile is less than 25 feet long its top is now below the hammer (see Fig. 1, Plate —*), and it is easy to pull it back to its position between the leads. This condition of affairs is shown, in the figure. If it is more than 25 feet long the top now projects above the hammer, as shown on Plate —.*

In either case, 1 and 2 haul the bottom into place; No. 2 drives a staple 2 feet from the end to receive the nozzle of the jet pipe; this done, 1, 2, 3, 4, 5, 6 raise the jet pipe from its position of rest, and lower it; 2 guides the nozzle into the staple, and the whole is forced down till the shoulder at the end of the nozzle rests on the staple. The point of the nozzle is now 6 inches below the end of the pile, as shown in the figures above referred to.

With a short pile (25 feet and under) 3, 4, and 5, 6 now pass one end of handy lines between the leads, round the pile, and back between the leads. The other end of the handy line is permanently fastened to the leads ladder. All this is shown in the figure. When the pile is in place, the wooden toggles shown at *a* and *b* are inserted in the toggle irons, and all is ready for driving.

With a long pile (30 feet and above) the following method of handling is employed.

Nos. 3 and 5 pass the handy lines round the pile as before, but Nos. 4 and 6 now take three turns with the free end round the ladder timber. The pile is of necessity supported so near the center of gravity that it assumes the position shown in dotted lines while the jet pipe is being attached.

Nos. 3 and 5 now bear all their weight on the handy lines, and 4 and 6 take in the slack as soon as 3 and 5 give it to them. In this way the pile is brought into position shown in full lines. The master driver now slacks away on the log-chain line, and the pile and jet pipe begin so settle. As soon as the butt has reached a depth of 4 feet, it is powerfully drawn down-stream by the current till it rests against the down-stream lower toggle, and this has a tendency to draw the top of the pile away from the leads. In severe currents, 3, 4, 5, and 6 have all they can do to hold it. As the pile is lowered the strain of the handy lines becomes more and more oblique till the position shown in dotted lines is reached. Here they support the pile of themselves. Nos. 3 and 4 now shift their line to its original horizontal position, 5 and 6 meanwhile holding the pile alone. As soon as the shift is complete, 5 and 6 change their line, and all proceeds as before, till the top of the pile is lower than the bottom of the hammer, when it is secured like a short pile. The pile (either long or short) is now lowered by the master driver slacking away on the log-chain line till within a few feet of the bottom; the jet pump is now started, and also the engine.

The pile is lowered till it rests on bottom, when it sinks slowly under the action of its own weight and the undermining action of the jet. The log-chain is now removed. The master driver takes hold of the friction lever (*c*), throws the friction into gear, and as soon as the hammer has been raised from its place of rest, 6 removes the rest, the engineer reverses the engine, and the hammer slowly descends to the top of the pile. A rapid descent of 8 or 10 feet in as many seconds frequently follows. When the downward motion of the pile becomes sluggish, the master driver raises and drops the hammer (which is permanently fast to the hammer line) by throwing the frictions in and out of gear. The best results in average bottom are obtainable by a quick succession of blows of between 6 inches and 1 foot.

When the pile has reached the required depth the pump is stopped, the hammer raised and toggled aloft by No. 6, and all is in the condition in which this description found it.

The above shows the operations to be performed. The time required for each is obtained from the following notes taken last summer:

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* Plate not forwarded.

TABLE I.—*Observed epochs.*

Number of observation.	Manipulations.			Pump.				Pile I.				Hammer.			Penetration.										Number of driver.	Remarks.
	Driver in position.	Pile seized by chain.	Pile ready to go in leads.	Pile in leads.	Pump starts.	Pump stops.	Number of strokes.	Kind of pump.	Size of jet.	Length.	Diameter of butt.	Sharp or not.	Number of blows.	Maximum fall.	Minimum fall.	Depth of water.	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.		
	h. m.	h. m.	h. m.	h. m.	m. s.	m. s.			In.	Ft.	In.			Ft.	Ft.	Ft.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.		
1	3 27	.....	.....	4 11	.....	.....	.....	C.	1	52	18	Yes	..	.....	.....	24	11 15	12 00	12 20	14 00	15 00	16 00	.....	.....	2	Begin to sharpen at 3h 37m; sharpened at 3h 46m; cut off in 9m. Master driver, Years.
2	4 30	.....	.....	4 56	.....	.....	.....	C.	1	47	18	Yes	.....	.....	.....	24	57 30	58 00	58 35	a58 55	2 30	3 45	6 30	.....	2	Begin to sharpen at 4h 37m; sharpened at 4h 43m.
3	8 18	.....	.....	8 50	.....	.....	.....	W.	1	48	10	No	.....	.....	.....	23	55 15	57 15	58 00	59 50	1 55	2 55	3 30	.....	1	Went for pile in skiff; returned to driver at 8h 32m. Master of driver, Joe Smieder.
4	.....	.....	.....	8 53	.....	.....	.....	Ca	1	47	12	No	.....	.....	.....	23	54 30	55 20	55 35	55 53	56 50	59 30	0 15	1 30	2	
5	9 13	.....	.....	b9 35	.....	.....	.....	W.	1	50	13	No	.....	.....	.....	23	49 35	51 10	52 50	53 05	53 25	53 35	54 00	.....	1	Had to go for pile in skiff.
6	9 15	.....	.....	9 42	.....	.....	.....	C.	1	44	13	No	.....	.....	.....	23	44 45	46 33	47 10	49 12	52 00	.....	.....	.....	7	Pipe came off when pile was partly down; nozzle found stopped with wood; pile finally broke off when 10 feet down.
7	10 10	.....	.....	c10 24	.....	.....	.....	W.	1	45	12	Yes	.....	.....	.....	23	33 00	37 30	37 35	d37 40	42 00	42 30	44 00	.....	7	Begin to sharpen at 10h 15m; sharpened at 10h 22m; Kehoe, master driver.
8	10 00	.....	.....	10 15	.....	.....	.....	C.	1	45	13	Yes	.....	.....	.....	23	20 30	21 40	21 55	22 20	22 50	23 10	24 00	.....	2	Begin to sharpen at 10h 04m; sharpened at 10h 08m; pile is very crooked.
9	10 13	.....	.....	10 40	.....	.....	.....	W.	1	48	16	Yes	.....	.....	.....	23	44 00	44 15	45 50	46 30	47 30	48 30	e55 00	.....	1	Begin to sharpen at 10h 17m; sharpened at 10h 26m.
10	11 23	.....	.....	11 47	.....	.....	.....	C.	1	42	14	No	.....	.....	.....	22	48 10	48 34	48 47	49 15	49 50	50 45	51 30	.....	2	Another driver in the way; delayed getting into position; had to get pile by skiff in a severe cross-current.

a Toggle stopped work of hammer from 4h 59m to 5h 02m.
b Pipe came off in lowering pile, having caught on toggle. In leads second time at 9h 45m.
c Pipe came off pile.
d In leads second time at 10h 32m. Toggles catch pile going down.
e Had to cut broken head off pile in leads, it was so crushed, between 12 and 14 feet penetration.

TABLE I.—*Observed epochs*—Continued.

Number of observation.	Manipulations.				Pump.					Pile I.			Hammer.			Penetration.										Number of driver.	Remarks.
	Driver in position.	Pile seized by chain.	Pile ready to go in leads.	Pile in leads.	Pump starts.	Pump stops.	Number of strokes.	Kind of pump.	Size of jet.	Length.	Diameter of butt.	Sharp or not.	Number of blows.	Maximum fall.	Minimum fall.	Depth of water.	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.		
	h. m.	*h. m.*	*h. m.*	*h. m.*	*m. s.*	*m. s.*			*In.*	*Ft.*	*In.*			*Ft.*	*Ft.*	*Ft.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*		
11	.....	.....	.....	1 50	.....	.....	600	W.	1	45	12	No	....	....	....	12	54 50	55 05	56 15	56 40	57 40	58 50	59 35	10 25[a]	7	Hard bottom.
12	.....	.....	.....	1 50	.....	.....	.....	C.	1	47	11	No	....	....	....	12	55 20	55 30	55 45	56 15	56 45	56 50	58 00	59 10	2	
13	2 17	.....	2 26	2 41	.....	.....	.....	W.	1	.....	.....	No	....	....	....	12	44	45 45	48 30	48 45[b]	51 15	55 00	.....	.....	7	
14	2 17	.....	2 30	2 36	.....	.....	582	C.	1	43	12	No	....	....	....	12	42	42 20[c]	46 30	46 35	47 13	47 30	47 55	48 15	2	
15	3 08	.....	3 19	3 32	.....	.....	2 12	W.	1	.....	.....	No.	....	....	....	12	38	38 15	39 30	39 40[d]	45 30	47 25	.....	.....	7	Jet pipe came off when pile struck bottom. Raised pile and replaced pipe.
16	3 08	.....	3 14	3 21	.....	.....	3 15	C.	1	45	13		....	....	....	23	23 24	24 30	25 10	25 35	25 50	26 12	26 25	26 50	2	Start for pile at 3[h] 00.[m].
17	8 50	.....	9 16	9 20	.....	.....	7 15	W.	1	37	16	No.	....	....	....	18	18 23	23 40[e]	33 00	35 00	35 10	35 25	36 30	36 35	7	Pile was drawn under the flat by the current while attempting to get in leads. Cut off between 9[h] 10[m] and and 9[h] 15[m].
18	8 50	.....	8 57	9 00	.....	.....	4 70	C.	1	38	14	No.	....	....	....	18	18 04	4 43	4 58	5 30	5 45	6 00	6 05	7 00	2	Start for pile at 8[h] 51[m]. Cut off between 8[h] 53[m] and 8[h] 56[m].
19	9 46	.....	9 56	10 03	.....	.....	4 28	C.	1	37	13	No.	....	....	....	18	18 04	4 10	4 20	5 30	6 25	6 26	6 30	8 00	2	Start for pile at 9[h] 51[m]. Cut off between 9[h] 52[m] and 9[h] 55[m].
20	9 46	.....	(*f*)	10 45	.....	.....	1 90	W.	1	36	13	No.	....	....	....	18	18 45	45 14	45 15	45 30	45 50[g]	46 00	46 15	46 35	7	
21	10 58	.....	11 19	11 23	.....	.....	.....	C.	1	36	16	Yes.	....	....	....	18	18 29	29 40	30 15	30 20	30 50	31 15	31 45	32 46	2	Cut off between 11[h] 05[m] and 11[h] 12[m]. Sharpen when in leads between 11[h] 13[m] and 11[h] 19[m].
22	10 58	.....	11 23	11 28	.....	.....	2 78	W.	1	35	15	No.	....	....	....	18	18 29	32 18	32 50	33 45	34 00	35 00	35 10	.....	7	Start to get pile over the deck of flat, at 11[h] 05[m]; on flat ready to cut-off 11[h] 15[m]. Cut-off at 11[h] 21[m].
23	1 40	.....	1 50	1 53	.....	.....	.....	C.	1	35	14		....	....	....	17	17 55	56 40	56 55	57 20	57 55	58 20	0 50	2 55	2	Start to get pile at 1[h] 45[m]. Cut off between 1[h] 46[m] and 1[h] 49[m].

24	1 40	.....	1 51	1 53	.....	.....	.....	W.	1	48	14	No.	..	...	.....	17	17 58	59 15	0 20	0 35	1 35	2 50	3 30	.....	1	Start to get pile at 1h 45m.
25	1 40	.....	.....	1 57	.....	.....	.....	W.	1	35	14	Yes.	..	...	.....	17	0 30	0 37	0 45	1 40b	6 00	6 35	8 30	.....	1	
26	2 25	.....	2 50	2 52	.....	.....	.....	C.	1	35	14	No.	....	...	.....	18	55 20	55 30c	0 20	2 15	2 20	2 30	3 30	3 50	2	
27	2 25	.....	.....	2 36	.....	.....	.....	W.	1	36	14	Yes	....	...	.....	18	44 00	46 20	46 25	47 05	47 18	48 40	49 10	50 40	1	Passed to this driver by No. 2.
28	2 25	.....	2 41	2 50	.....	.....	.....	W.	1	34	13	Yes.	....	...	.....	18	52 10	52 15	52 40	53 40	54 25	56 00	.....	.....	7	Begin to cut off pile at 2h 33m. Cut off at 2h 38m, also sharpen somewhat.
29	3 30	.....	3 39	4 02	.....	.....	.....	C.	1	38	13	No.	....	...	.....	20	4 05	4 15	4 25	6 30	6 35	6 40	7 40	8 40	2	Driver passed pile 30 and 31. Each transfer required about three minutes.
30	3 30	.....	.....	3 45	.....	.....	.....	W.	1	40	10	No.	....	...	.....	20	53 00	53 15	54 00j	56 00	57 00	.....	.....	.....	1	
31	3 30	.....	4 08	4 13	.....	.....	.....	W.	1	35	16	No.	....	...	.....	20	13 45	15 20	17 00	19 00	.....	.....	.....	.....	7	Hard bottom.
32	4 50	.....	4 55	5 01	.....	.....	.....	W.	1	43	14	No.	....	...	.....	20	7 35	9 15	10 00	11 05k	13 00	15 00	.....	.....	1	Hard bottom; jet seems to have no effect whatever.
33	8 39	.....	8 50	8 52	.....	.....	5 27	W.	1	32	15	No.	....	...	.....	2	55 30	55 55	59 15	59 30	59 40	2 22l	3 20	.....	18	Master driver is Kelly.
34	9 15	.....	9 22	9 27	.....	.....	4 00	W.	1	32	16	No.	....	...	.....	2	34 00	36 50	36 50	37 15	38 45	39 45	41 15	.....	18	
35	1o 09	.....	10 14	10 21	.....	.....	3 47	W.	1	33	17	No.	....	...	.....	2	22 30	22 30	22 30	25 00	25 05	25 50	25 55	.....	18	Pile goes down so fast as to catch toggle.
36	10 27	.....	10 49	11 01	.....	.....	13 29	W.	1½	24	18	No.	....	...	.....	4	4 30	4 45	5 00m	10 10	12 00	16 00	.....	.....	18	
37	1 40	.....	1 45	1 53	.....	.....	5 20	W.	1½	24	17	No	....	...	.....	4	54 00	55 20n	56 10	57 10*	57 10	58 10o	0 45	.....	18	(*) Hammer placed on pile.
38	2 05	.....	2 20	2 23	.....	.....	3 50	W.	1	24	17	No	....	...	.....	4	24 00	24 30	25 30	27 00	27 30	28 50	29 30	.....	18	
39	3 05	.....	3 20	3 38	.....	.....	6 47	W.	1½	24	16	No	....	...	.....	2	38 55	39 10	39 40*	40 15	41 15	41 50†	43 00‡	44 15	18	(†) Hammer on pile. (‡) Begin to strike with hammer. (§) Had to stop to white-lead friction, it slipped so badly.
40	4 09	.....	4 47	4 54	.....	.....	2 18	W.	1½	26	10	No	....	...	.....	3	55 25	55 35	55 40	56 15	56 35	57 00	57 15	57 30	18	
41	9 50	.....	9 56	.....	.....	.....	1 35	W.	1½	22	10	No	....	...	.....	5½	1 25	1 30	2 00*	.....	.....	.....	.....	.....	18	(*) Went down so fast that hammer broke the toggles, and the whole pile came out of the leads; raise and redrive as pile 42.
42	9 50	.....	10 03	10 13	.....	.....	1 70	W.	1	22	10	No	15	§	§	5½	15 15	15 20	15 30*	16 29	16 50	17 10	17 30	17 40	18	(*) Hammer on pile, eleven minutes wasted in getting pile properly in leads.
43	9 28	.....	9 43	9 49	49 50	54 00	3 57	W.	1½	24	15	No	5	2	1	5½	50 25	51 10	53 00*	53 20	53 35	53 40p	.....	.....	18	(*) Hammer on pile.
44	9 30	.....	9 43	9 49	.....	.....	.....	W.	1	26	10	No	....	2	½	12	50 00	50 55	51 50	52 10	52 30	57 00	.....	.....	7	
45	.....	.....	.....	10 00	4 00	9 00	3 84	W.	1½	24	15	No	.....	.....	.....	5½	4 15	5 00	5 10	*5 25	6 50	7 40	9 10	.....	18	(*) Stop to arrange toggles.

a Jet came off pile, and the pipe was raised out of the way; jet had caught in toggle.
b Pipe came off pile. Start to get pipe at 2h 22m. Cut off pile in leads between 2h 26m and 2h 32m.
c Belt of engine-hammer cramped in leads outside of pile. Start for pile at 2h 25m; cut off between 2h 37m and 2h 30m.
d Head of pile broke off, and friction began to slip so badly that the hammer was with trouble raised.
e Kehoe got his pile jammed in the toggle and wasted 10m.
f Start for pile at 9h 53m. Kehoe used too small lines to raise pile. It broke twice. He also cut pile off in wrong place, and so had to cut off again.
g So far by jet alone.
h Pile came loose in leads. Had to stop to fasten toggle and lines.
i Toggles catch piles. Driver passed a pile to No. 1 (pile 27) before getting one for itself.
j Hard bottom.
k Pipe caught in toggle. *l* Adjusting toggles and pipe.
m Kehoe got his line round our pile. During this delay the jet pipe got ahead of the pile as it was only lashed to the latter, thus losing most of its efficiency.
n So far by jet alone.
o Sudden slowing of speed of penetration.
p Bottom toggle came out, letting pile run too far up-stream; pull up and drive as 45.

TABLE I.—*Observed epochs*—Continued.

Number of observation.	Manipulations.				Pump.					Pile I.			Hammer.			Depth of water.	Penetration.								Number of driver.	Remarks.
	Driver in position.	Pile seized by chain.	Pile ready to go in leads.	Pile in leads.	Pump starts.	Pump stops.	Number of strokes.	Kind of pump.	Size of jet.	Length.	Diameter of butt.	Sharp or not.	Number of blows.	Maximum fall.	Minimum fall.		2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.		
	h. m.	h. m.	h. m.	h. m.	m. s.	m. s.			In.	Ft.	In			Ft.	Ft.	Ft.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.		
46	10 01	.....	10 26	10 33	.....	.....	.....	W.	1	22	16	Yes	.....	.....	.....	12	33 45	33 45	33 50	34 00	34 40	35 15	.....	.....	7	Delay caused by sharpening.
47	10 12	.....	10 20	10 33	32 45	49 30	10 38	W.	1¼	24	18	No	133	6	1	5½	33 15	34 25	34 40	*36 10	37 30	†39 30	42 50	45 00	18	(*) Reload friction. (†) Stop hammer to adjust toggles and lines.
48	.....	.....	.....	1 37	39 00	43 00	2 34	W.	1	22	10	No	10	5	½	5½	40 15	40 35	41 30	41 32	42 15	42 35	42 40	43 00	18	
49	1 58	.....	2 01	2 09	9 35	27 30	8 18	W.	1	24	18	No	.....	.....	.....	6	10 40	11 40	a12 35	15 10	18 45	24 10	.....	.....	18	
50	3 18	.....	3 26	3 35	.....	40 50	4 49	C.	1	36	17	Yes	....	6	1	18	35 30	35 32	35 34	36 30	37 00	37 15	38 30	39 00	2	
51	3 50	.....	4 05	4 10	9 45	15 25	4 88	C.	1¼	38	15	No	.....	.....	.....	18	10 05	10 07	10 10	*10 15	12 20	12 30	13 00	14 20	2	(*) Stopped hammer to remove toggles; Years says that piles driven without small nozzle generally go hard beyond 14 feet.
52	4 29	.....	4 51	4 53	54 50	58 52	3 11	C.	1	38	16	Wedge.	....	4	1	18	55 30	55 35	55 40	56 15	56 35	56 55	57 30	58 30	2	
53	.....	8 00	2 40	2 43	45 17	51 15	4 62	C.	1	36	18	No	....	6	½	19	45 30	46 30	46 55	47 45	49 15	51 15	.....	.....	12	Cut off where is 10 inches in diameter in 6m.
54	3 00	8 00	3 10	3 12	13 30	18 25	4 10	C.	1	35	18	No	....	.....	.....	19	14 00	14 55	15 20	16 20	17 35	18 25	.....	.....	2	
55	3 26	.....	3 32	3 39	39 30	44 15	3 76	C.	1	35	18	No	....	10	....	19	40 00	40 50	41 50	43 00	44 15	.....	.....	.....	2	Pile goes hard; settles 1 inch per 10-foot blow, at 3h 44m; chop pile to clear the head which had jammed in the leads till 3h 55m.
56	4 03	.....	4 31	4 34	35 40	39 55	3 52	C.	1	35	17	Yes	....	.....	.....	17	36 15	37 05	37 35	37 50	38 30	39 15	.....	.....	2	Pile was brought up wrong end up-stream; delay in turning it; cut off where 12 inches in diameter in 7m 30s.
57	4 52	.....	4 58	5 04	5 25	12 10	5 42	C.	1	35	18	No	....	.....	.....	17	6 00	6 30	8 15	10 20	12 10	.....	.....	.....	2	Toggles delay 1m.
58	8 43	.....	9 01	9 03	3 20	14 18	5 30	W.	1	28	14	No	94	12	¼	10	4 00	5 10	5 35	*6 00	9 00	11 30	13 35	.....	7	(*) Toggle came out, delay 2m; took a line round the pile and back to winch to help toggles hold the pile.
59	9 19	.....	9 26	9 31	30 30	35 27	2 50	W.	1	29	13	Wedge	30	4	½	10	31 30	32 00	*33 00	33 20	33 45	34 20	.....	.....	7	2m to sharpen to half wedge. (*) Hammer on pile.

60	9 50	.....	9 57	10 00	59 50	5 20	2 38	W.	1	28	17	Wedge	4	16	1	9	0 30	0 40	1 05	1 30	2 45	3 45	4 45	....	7								
61	10 52	53 00	10 57	10 58	58 55	2 52	1 97	W.	1	30	9	Half wedge	45	16	½	11	59 10	59 30	0 30	*0 40	0 45	0 55	1 20	2 30	7	Sharpen to half-wedge takes 2m.							
62	9 07	10 50	9 12	9 13	No pump used.....					29	10	Yes	86	5	3	10	15 05	15 06	16 18	17 25	30 55	32 08	.....	.....	10	Master driver Dennis Dent; oak pile driven through mattress; head crushed after thirty-six blows of 3 feet each.							
63	10 19	20 20	10 22	10 22½	No pump used.....					30	11	Yes	113	8	3	12	25 45	26 55	27 45	30 30	33 50	.....	.....	.....	10	Oak pile head crushed after one hundred and thirteen blows.							
64	10 54	59 05	11 01	11 02	No pump used.....					29	10	Yes	93	6	3	8	5 22	5 53	*6 00	14 30	16 45	.....	.....	.....	10	Oak pile split after eighteen blows of 6 feet each.							
65	9 46	46 10	9 47	9 50	No pump used.....					30	15	Yes	83	24	8	12	52 00	53 40	54 40	55 50	56 50	58 30	1 20	.....	10	Sycamore pile head in excellent condition after eighty-three blows, many of them 24 feet.							
66	10 07	8 10	10 10	10 12	No pump used.....					30	9	Yes	103	10	8	12	12 45	13 30	14 25	15 22	16 33	19 55	.....	.....	10	Sycamore pile head was only 8 inches in diameter; was but little injured after one hundred and three blows.							
67	10 26	26 20	10 27	10 29	No pump used					20	11	Yes	46	16	8	12	30 12	30 55	31 40	32 30	33 15	34 30	.....	.....	10								
68	10 43	44 00	10 45	10 46	No pump used.....					30	10	Yes	92	10	7	12	47 15	48 50	49 45	50 55	51 50	53 30	.....	.....	10	Sycamore pile; head in excellent condition.							
69	1 37	39 50	1 41	1 46	47 55	50 00	94	W.	1	43	12	No	14	10	3	28	48 25	*48 50	49 03	49 45	50 10	50 45	51 00	.....	9	Sternecker, master driver.							
70	1 58	0 00	2 01	b2 08	28 25	32 30	1 27	W.	1	42	10	No	20	8	3	28	29 30	30 00	32 00	32 10	32 30	33 45	.....	.....	9								
71	2 39	40 00	2 43	3 00	00 35	4 00	5 46	W.	1	46	14	No	42	18	3	28	0 30	0 32	1 10	1 50	4 00	6 45	9 00	.....	9	Toggles delay getting pile in leads 10m; bottom toggle later delays 2m.							
72	3 17	19 36	.....	3 30	31 00	36 40	3 01	W.	1	48	15	No	41	20	3	28	32 00	32 30	33 50	34 45	35 00	39 00	.....	.....	9	Cottonwood pile stood a remarkable number of blows, none less than 8 feet before head crushed.							

a Attach rope to pile to help toggle, at 2h 14m. Belt off engine, then hammer line broke. Leave for No. 2 driver. *b* Hammer line parted, 20m to replace; toggle delay 1½m.

The abbreviations used in the above table are as follows: In column 9, C.=Cameron pump; W.=Worthington pump. In column 10, 1 inch means that the usual form of nozzle was used; 1¼ inches mean that no reducer whatever was employed. In the latter case the jet pipe had no shoulder to rest on a staple, and it was consequently lashed to the pile. This caused much delay in attaching and detaching the jet.

Table II, derived directly from Table I, shows the intervals between the recorded times corresponding to the two epochs named at the head of each column. It contains only data applicable to the part of the report under present consideration.

TABLE II.—*Time intervals.*

No. of observation.	Dimensions, &c.							Time (minutes) which may perhaps be shortened.					Time (minutes) which should be entirely avoided.					
	Feet driven.	Length of pile.	Diameter of butt.	Sharp or not.	Depth of water.	Gallons used in jet.	Size of nozzle.	Needed time of pile in leads to pile driven down.	To put driver in position.	Pile fast to log-chain to pile ready to go in leads.	Driver in position to pile ready to go in leads.	Pile ready to go in leads to pile in leads.	Driver in position to pile in leads.	Driver in position to log-chain fast to pile.	Delays caused by toggles.	Delays caused by jet pipes catching.	Delays caused by inefficient pile supply.	Delays caused by cutting off pile.	Delays caused by sharpening pile.
	Ft.	*Ft.*	*In.*		*Ft.*		*In.*	*Sec.*											
1	12	52	18	Yes	24		1	300	14.0				43					9	9
2	14	47	18	Yes.	24		1	630					26		3				6
3	14	48	10	No.	23		1	810	9.5				32				15		
4	16	47	12	No.	23		1	510	13.5										
5	14	50	13	No.	23		1	540	19.0				22			10			
6	10	44	13	No.	23			600	8.0				27						
7	14	45	12	Yes.	23		1	720					14		8	4			7
8	14	45	13	Yes.	23		1	540	59.0				15						4
9	14	48	16	Yes.	23		1	840					27						9
10	14	42	14	No.	22		1	270					24				7		
11	16	45	12	No.	22		1	1,225							10				
12	16	47	11	No.	10		1	400											
13	12			No.	22		1	840			9	13	24			5		6	
14	16	43	12	No.	22		1	735			13	6	19		4			3	
15	12			No.	22		1	925			11	3	24						
16	16	45	13		23		1	350			6	7	13		10				
17	16	37	16	No.	18		1	995			26	4	30					5	
18	16	38	14	No.	18		1	420			7	3	10					3	
19	16	37	13	No.	18		1	300			10	7	17					3	
20	16	36	13	No.	18		1	95					59						
21	16	36	16	Yes.	18		1	586			21	4	25					7	6
22	14	35	15	No.	18		1	430			25	5	30					7	
23	16	35	14		17		1	595			10	3	13					3	
24	14	48	14		17		1	630			11	2	13						
25	14	35	14	Yes.	17		1	600					17		5				
26	10	35	14	No.	18		1	710			25	2	27		5				
27	16	36	14	No.	18		1	760					13						
28	12	34	13	Yes.	18		1	360			16	9	25					5	
29	16	38	13	No.	20		1	400			29	3	32						
30	10	40	10	No.	20		1	720					15						
31	8	35	16	No.	20		1	360			38	5	43						
32	12	43	14	No.	20		1	840			5	6	11						
33	14	22	15	No.	2		1	680	11.7		11	2	13		2	3			
34	14	22	16	No.	2		1	855	27.7		7	5	12						
35	14	23	17	No.	2		1¼	205	1.1		5	7	12						
36	12	24	18	No.	4		1¼	900	24.0		22	12	34						
37	14	24	17	No.	4		1¼	465	1.3		5	7	13						
38	14	24	17	No.	4		1	390	35.5		15	3	18						
39	16	24	16	No.	2		1¼	375	24.7		15	16	33						
40	16	26	10	No.	2		1¼	210			36	9	45						
41	6	22	10	No.	5¼		1¼	120			6								
42	16	22	10	No.	5¼		1	280	10.3		13	10	23		11				
43	12	24	15	No.	5¼		1¼	280			15	6	21						
44	12	26	10	No.	12		1	480	4.0		13	6	29						
45	14	24	15	No.	5¼		1¼	550	2.9						1				
46	12	22	16	Yes.	12		1	135			25	7	32						
47	16	24	18	No.	5¼		1¼	720			8	13	21						
48	16	22	10	No.	5¼		1	360											
49	12	24	18	No.	6		1	900	53.0		3	8	11						
50	16	36	17	Yes.	18		1	240	11.0		8	9	17						
51	16	38	15	No.	18		1¼	260	14.7		15	5	20		2				
52	16	38	16	Wedge	18		1	330			22	2	24						
53	12	36	18	No.	19		1	495		1		3						6	
54	12	35	18	No.	19		1	385	5.6	2	10	2	12	8					
55	10	35	18	No.	19		1	315	18.7	1	6	7	13	5				11	
56	12	35	17	Yes.	17		1	315	12.7		28	3	31					7½	5
57	10	35	18	No.	17		1	490			6	10	16		1				
58	14	28	14	No.	10		1	635	5.4	1	18	2	20	17	2		17		

TABLE II.—*Time intervals*—Continued.

	Dimensions, &c.							Time (minutes) which may perhaps be shortened.						Time (minutes) which should be entirely avoided.					
No. of observation.	Feet driven.	Length of pile.	Diameter of butt.	Sharp or not.	Depth of water.	Gallons used in jet.	Size of nozzle.	Needed time of pile in leads to pile driven down.	To put driver in position.	Pile fast to log-chain to pile ready to go in leads.	Driver in position to pile ready to go in leads.	Pile ready to go in leads to pile in leads.	Driver in position to pile in leads.	Driver in position to log-chain fast to pile.	Delays caused by toggles.	Delays caused by jet pipes catching.	Delays caused by inefficient pile supply.	Delays caused by cutting off pile.	Delays caused by sharpening pile.
	Ft.	*Ft.*	*In.*		*Ft.*		*In*	*Sec.*											
59	10	29	13	Half wedge.	10	...	1	200	15.7	2	7	5	12	5	....	....	....	....	2
60	14	28	17	Half wedge.	0	...	1	225	46.3	5	7	3	10	1	....	....	....	....	....
61	16	30	9	Half wedge.	11	...	1	270	.....	...	5	1	6	0	....	....	....	....	2
62	13	29	10	Yes.	10	None.	.....		46.9	1	5	1	6	4	....	....	....	....	....
63	10	30	16	Yes.	12	None.	680		78.8	2	3	½	3½	1	....	....	....	6	....
64	10	29	10	Yes.	8	None.	885		33.3	2	7	1	8	5	....	....	....	5	....
65	14	30	15	Yes.	12	None.	680		10.7	1	1	3	4	0	....	....	....	....	....
66	12	30	9	Yes.	12	None.	475		9.1	2	3	2	5	1	....	....	....	....	....
67	12	29	11	Yes.	12	None.	330		11.1	1	1	2	3	0	....	....	....	....	....
68	12	30	10	Yes.	12	None.	450		.....	1	2	1	3	1	....	....	....	....	....
69	14	43	12	No.	28	...	1	300	17.6	1	4	5	9	3	....	....	....	....	....
70	12	42	10	No.	28	...	1	345	26.3	1	3	7	10	2	1¼	....	....	....	....
71	14	46	14	No.	28	...	1	540	21.0	3	4	17	21	1	12	....	....	....	....
72	12	48	15	No.	28	...	1	540	....	0	2	11	13	2	....	....	....	....	....
Sum.	976	2,434	975	.....	1,114	...	...	37,736	526.1	27	628	295.5	1273.5	56	77.5	22	39	66 5	50.0
Mean.	13.6	34.8	13.9	.....	15.5	...	...	524	15.8	1.7	11.9	5.6	17.7	3.3	1.8	0.3	0.6	1.2	0.7

The numbers in the above table show such large variations in the time required to perform the same work under different circumstances that the means are plainly too uncertain to afford a reliable basis for estimating the absolute average time required for each. While this is the case in regard to these means as absolute values, their relative sizes afford a satisfactory means of subdividing the total time required to drive a pile, if this element be obtained from independent and more extended data. This can be obtained with great accuracy from the official records of the number of hours the drivers were at work *driving* and the total number of piles driven.

These figures for the last eighteen months are obtained from the following table:

TABLE III.—*Eighteen months' pile record.*

Locality.	No. of piles driven.	Hours driving.	Locality.	No. of piles. driven.	Hours driving.
Engineer Depot	102	140	Chesley Island	382	426
Horsetail Bar	5,995	7,118	Jim Smith's	4,376	4,824
Arsenal Island	335	372	Foster's Island	66	71
Twin Hollows:			Wahoo	2,639	3,206
East side	1,611	2,033			
West side	6,330	7,375	Total	23,103	27,899
Beard's Island	1,267	1,334			

Dividing the total number of working hours in the last eighteen months (27,899) by the total number of piles (23,103), the quotient is one and twenty-one one-hundredths hours, or seventy-three minutes; this is the true average time desired.

Referring to the means obtained from Table II—

	Minutes.
The time to put driver in position is	15.8
The time from driver in position to pile in leads is	17.7
The time from pile in leads to pile driven is	8.7
Total time required per pile	42.2

The discrepancy between the two values is to be anticipated from the following causes:

(1.) My presence made the master drivers do their very best.

(2.) I frequently noticed that drivers on which I was not present had to wait for piles to be brought to them, while those where I was located were generally kept well supplied.

To accurately distribute the cost of driving among the different operations, and thus to obtain a correct idea of the expense caused by each delay, I multiply each of the means obtained from Table II by the ratio $\frac{14.8}{13.9}$. The resulting product will approximate to the time actually devoted to each operation in the true average pile.

The following table shows these products:

TABLE IV.—*Time required in the true average pile.*

	Minutes.
Pile in leads to pile-driver	14.8
Pile fast to chain to pile ready to go in leads	2.9
Pile ready to go in leads to pile in leads	9.5
Driver in position to pile ready to go in leads	20.2
Driver in position to pile in leads	30.1
Driver in position to pile fast to chain	5.5
To put driver in position	26.9
Toggle delays	3.0
Inefficient pile supply delays	1.0
Jet pipe delays	0.5
Cutting off pile delays	2.0
Sharpening pile delays	1.2

The cost per hour of a driver and crew is approximately as follows:

Pay of master and engineer (with board)	$0 60
Pay of crew, six deck hands (with board)	90
Coal and oil consumed	09
Total per hour	1 59

Multiplying the figures in the last table by 20,000 in round numbers the number driven in eighteen months, I obtain the first column of Table V.

TABLE V.—*Cost per 20,000 piles—labor.*

Minutes.	Hours.	Cost.	
296,000	4,933	$7,843 47	Pile in leads to pile driven.
58,000	966	1,535 94	Pile fast to chain to pile ready to go in leads.
404,000	6,733	10,705 47	Driver in position to pile ready to go in leads.
190,000	3,166	5,033 94	Pile ready to go in leads to pile in leads.
602,000	10,033	15,952 47	Driver in position to pile in leads.
110,000	1,833	2,914 47	Driver in position to pile fast to log-chain.
538,000	8,966	14,255 94	To put driver in position.
60,000	1,000	1,590 00	Toggle delays.
20,000	333	529 47	Inefficient pile supply delays.
10,000	166	264 74	Jet pipe, delays.
40,000	666	1,058 94	Cutting off pile delays.
24,000	400	636 00	Sharpening pile delays.
2,352,000	39,195	62,320 85	To drive 20,000 piles.

The above figures refer solely to the cost of labor.

The figures in this table are exceedingly expressive; they show with clearness that any saving of time, even of a fractional part of a minute per pile, is really an important economy.

I shall now consider these items in detail and suggest all changes—first, in personnel; second, in plant—which seem to offer chances of improvement.

(1.) *Pile in leads to pile-driver.*—This time depends on two independent conditions. The nature of the bottom, depth of water, and strength of current are beyond control. They form the first condition. The second is the individual skill of the master driver and crew, both in the actual handling of the friction lever and also avoiding delays from the toggles and jet pipe.

After a pile begins to sink it rarely requires more than five minutes to sink 12 feet, unless the action of the hammer is stopped, but with most of the master drivers this is necessarily done to adjust the toggles or to free the jet pipe, as their crew is not sufficiently well trained. This time in the table is much greater than it would be with master drivers of a higher class. The absolute extent of these delays during driving I found it impossible to record, as there were no distinct epochs marking their beginning and end. Frequently the hammer was not absolutely stopped, but only lifted a few inches from the pile and the engines stopped. I estimate that about five minutes were wasted in driving most of the piles from these combined causes.

In really hard bottom to settle the pile to its full depth requires fully twelve or fifteen minutes.

(2.) *Pile fast to chain to pile ready to go in leads.*—This operation has given no trouble, and there does not seem to be any chance for improvement.

(3) *Driver in position to pile ready to go in leads.*—This is made up of the lesser times—*driver in position to pile fast to log-chain, pile fast to chain to pile ready to go in leads*, and the time to attach the jet pipe and remove kinks from the hose. The first is five and five-tenths minutes, the second two and nine-tenths minutes, and the last must be the total time, less the sum of the other two, that is eleven and eight-tenths minutes.

The first of these three subordinate times should never occur, as only two of the crew are needed to move the flat; the other four should have selected the new pile, and made it fast to the chain long before the change of position is complete. With the best drilled crew this was always successfully accomplished.

The second subordinate time has been discussed above.

The long time required to perform the third subordinate operation was largely due to the inferior quality of staples used. They were generally unsharpened and were too soft: they often bent so badly under the blows of the maul used to drive them into the pile that two or three were tried before one was driven far enough to hold. Their failure to hold is plainly shown in the remarks to the first twenty piles in Table I.

With better staples and a master driver capable of drilling his crew well, this eleven and eight-tenths minutes should be reduced at least half. If the piles were too long, or needed sharpening for use in gravel, these delays also entered the time under present consideration. At first sight it would appear that the mean "driver in position to pile ready to go in leads" should equal the sum of "driver in position to pile fast to chain," and "the latter to pile ready to go in leads," but the value of the latter mean is derived from a few of the last piles recorded, and it was unobserved for the greater part of the time I was observing, while the former was observed and recorded from the outset.

(4.) *Pile ready to go in leads to pile in leads.*—This time (9.5 minutes) does not seem unreasonable when the difficulty of handling a long heavy pile, with the lower end in a strong current, is considered. It may perhaps be lessened by a new form of toggle, which, however, has not yet been sufficiently tested to justify any definite statements.

(5.) *Driver in position to pile in leads.*—This is merely the sum of several lesser times which have been discussed, each in detail.

(6.) *Driver in position to pile fast to log-chain.*—This has been fully discussed under head 3.

(7.) *To put driver in position.*—This operation demands much skill in arranging lines on the part of the master driver, and the best means of decreasing this greatest single delay seems to be the employment of a better class of masters, or in having more than one leads on the same flat.

(8.) *Toggle delays.*—These delays are particularly vexatious. They are of frequent occurrence, and are hard to avoid. When the weight of the hammer is first placed on the pile, a sudden descent of 8 or 10 feet frequently occurs, and this is exceedingly apt to jam the pile against the present form of toggles, which are rigidly held to the *leads*. It seems to me to be very desirable to have some form of toggle which is made fast to the *pile*, and is free to slide in the leads. This would leave the pile free to descend as fast as it would, and would, moreover, hold the head truly under the center of the hammer, and thus save severe strains on the leader timbers. Two forms of sliding toggles have been devised and tested. The first was of wrought iron, and proved to be much too heavy and unwieldy.

The second is made of oak, weighs only 30 pounds, and has worked very satisfactorily in strong currents; where there is little or no current there is no appreciable advantage in its use, as in that case the old form of toggles must be used at the same time.

This second form of toggle holds the pile head from moving up stream under the influence of the current against the submerged part, but has no power to resist the opposite tendency which never occurs except in nearly still water. Its construction and dimensions are plainly shown in Plate —.* It also prevents any tendency of the pile to move laterally in the leads.

* Plate not orwarded.

(9.) *Inefficient pile supply.*—From the testimony of all connected with the works, this was one of the most frequent and irritating causes of delay. Piles were supplied to the drivers too long, or the supply was not kept up continuously, so that the crew often had to raft their own piles or sit and wait. During my observations such delays seldom occurred on the drivers when I was present, but I have often noticed others waiting idle, for more piles. A well-organized force to cut up the original pile rafts, and sort the piles, and another, or, better still, a steam launch, to tow the piles to each driver cut to exactly the proper length for its use should exist wherever pile driving on a large scale is in progress.

(10.) *Jet pipe delays.*—These are principally due to defective staples, which fail to hold the jet pipe to the pile, and to the square joint where the flexible hose joins the jet pipe proper. This shoulder is liable to catch on the platforms as the pile and pipe descend, and not infrequently raises the nozzle out of the staple. Sufficient care on the part of the leader boys is all that is required to prevent this. A coupling with a beveled edge in place of the square shoulder would, if not too expensive, be of great advantage.

(11.) *Cutting pile off.*—This would be avoided entirely by supplying the drivers with piles already of the proper length.

(12.) *Sharpening piles.*—With jet drivers this is seldom required. It is necessary when the bottom is clay or gravel, and when the butt is over 16 inches in diameter, and cut off square.

A half wedge with the jet pipe stapled to the side on which the wedge is cut, seems to be as efficient usually as a sharp point. The pile in this case sinks vertically. The pile can best be sharpened on the driver, as to do this easily the log has to be raised out of the water. To sharpen to a half wedge requires only between two and three minutes.

PAY AND CREW.

Study of the subject has led me to think that the organization of the crew, already described, admits of no improvement, but there is great need of some incentive to the master driver to do more work. That fifteen piles a day were driven when I was present and nine or ten when I was not is suggestive; and it seems to me that there is great evidence of a general tacit understanding among the masters that ten piles a day was to be the number considered as an average day's work, and that so long as no one exceeded that limit no one would be compelled to do so. This is indicated in many ways.

Several of the masters drove over twenty piles in a single day, when their average for the month had been so poor that they were threatened with discharge if they did no better. One who seemed to be independent of such combination averaged for the entire summer much above ten, and one day in an easy place drove thirty-five piles. Another suggestive fact is the unnatural uniformity of the rate of driving in easy and hard situations. That two drivers, one working in deep, swift water, the other in shallow and slack, should make the same average is significant, and that this uniformity does exist is at once seen by examining the official pile-record book.

Accepting some such understanding as a probable fact, the first necessity of good work is to break it up.

During the last eighteen months the masters have been paid by the month, and so long as they drove enough piles a day to retain their situations they had no inducement to overwork themselves.

The evident advantage of the system is that there is no temptation to make a large record by underdriving the piles, but the danger is that this desirable end may be more than balanced by the indifference of the master drivers about making rapid progress.

For the coming season I should recommend the following scale of pay, the object of which is to induce the masters to work hard by allowing their work over a certain number of piles to increase their pay.

The rate for a master driver to be $75, subsistence included. For this pay a monthly average of fifteen piles for every ten hours' work during the month is required. At the end of each month the total number of hours each master has worked is to be multiplied by fifteen and the result divided by ten. The result is the number of piles he should have driven to make the average fifteen. If he has driven more than this he is to receive 10 cents for each pile in excess. If less, he is to forfeit 20 cents for each pile he is short. If any master falls below an average of twelve piles he should be discharged. These numbers are given only as a standard. In very deep water, where the bottom is gravel or clay, there is no question but what fifteen piles is too much to expect of the most skillful master. The resident engineer, therefore, in making up the time-roll should state the number of piles driven by each master, and if the number falls below that required he should state whether in his judgment it was through the fault of the master or from the class of work he had been doing. In easy

positions the fifteen average should be twenty. All this must of necessity be left to the judgment of the resident engineer, who is on the spot. Otherwise great injustice could easily result from the system.

To form a clear idea of the relative cost of driving by last season's and by the proposed systems, the following examples are taken:

First. Assume that the average 15 is just attained:

Cost of driver and crew for 10 hours = $15.90.

The average cost per pile is therefore $\frac{15.90}{15} = \$1.06$ (subsistence included).

At last season's rate, to drive fifteen piles takes fifteen hours; the cost per pile is therefore $1.59 \times \frac{15}{15} = \$1.59$.

A saving of $1.59 − $1.06 is made = $0.53 per pile.

Each pile in excess of fifteen costs only 10 cents, as it takes no extra time of driver and crew. A clear saving is thus made of $1.59 (the cost per pile last year), diminished by $0.10 = $1.49.

The temptation to drive the piles to less than the required depth is great under the new system, and it seems advisable to employ an additional resident engineer at each work at which four or more drivers are employed, whose sole duty it is to watch the drivers, to organize and maintain an efficient force to supply the piles of the exact length to be used by each driver, and to keep the pile-record book. One of the resident engineers who has been on the work a year would make a much more efficient inspector than a new man would, and his place might be filled by a recent graduate from some engineering school, at the rate of $75 a month, subsistence included.

This sum, deducted from the saving made by the increased number of piles above assumed, gives the following results:

Assuming four drivers at work:

Number of piles driven a day = 60.

Daily pay of new resident engineer (subsistence included) = $3.00.

Cost of inspector per pile = $\frac{300}{60} = \$0.05$.

The saving is then $0.53 − $0.05 = $0.48 per pile.

Piles in excess of fifteen evidently increase the economy much, and examination shows that the deduction of 20 cents for a less number than fifteen also creates a saving over last year's ratio. It seems, therefore, that the result of applying the new system must be a considerable saving in money, and the pile inspector can keep very valuable records, which are difficult to obtain unless some one of that class is available for the purpose.

CHANGES IN PLANT.

With a view to determining the value of volume of water as compared with the velocity with which it issues from the nozzle, in the jet driving, I tried the experiment of driving a number of piles with no reducing nozzle at all. These are shown in Table I, in the column marked "Size of nozzle," by having a nozzle orifice of 1¼ inches. The effect, if any, seemed to be a slight increase in the speed of descent for the first 10 or 12 feet, followed by very hard driving. The rapidity at first was perhaps due to the large volume of water used, the hard driving to the nozzle being clogged from insufficiency of velocity to clear itself. To further test this point, I should recommend that one or two drivers be supplied with a jet pipe 2 inches in diameter, with two nozzles of the form shown on plate;* one with the orifice 1 inch, the other 1¼ inches in diameter. The question could then be definitely set at rest, and the expense would be slight.

Second. The form of reducer now in use seems to be capable of great improvement, as shown in Plate —.* One of these tapering nozzles was made by the regular blacksmith, and has given great satisfaction.

Third. The coupling between the jet pipe and hose should be made without the square shoulders it now has. These are continually catching on platforms and toggles.

Fourth. The rest which supports the hammer when aloft should be operated from the deck as shown in Plate —.*

Fifth. There should be, as shown on Plate —* a hinged portion of the upper part of the walls of the engine house, which could be opened in warm weather to allow the superheated air to escape. This would contribute immensely to the health and comfort of the engineers.

Sixth. There should be a chock placed in the window in the rear of the engine-house to save wear on the down-stream anchor lines when they are led to the steam winch.

Seventh. For some reasons it appears at first sight as though there would be great advantages in having the leads on the side of the flat, instead of on the end. By this

* Plate not forwarded.

means the flat always overlaps at least two piles already driven, which assists materially in alignment, but when such a large proportion of the work is done directly across strong currents the disadvantage of exposing the long side of the flat to the force of the water overbalances the advantage gained.

A complicated arrangement to preserve the trim of the flat is necessary when the leads are on the side. At Plum Point, where this kind of driver is employed, it has been found necessary to employ drivers with leads at the end to close gaps, and this of itself condemns the system, as it is very inconvenient to have two different forms of driver at work together, especially when one form is incapable of completing its own work.

PART II.—ACTION OF THE DRIVERS USED IN THE LAKE SHORE PROTECTION AT CHICAGO, ILLINOIS.

Through the kindness of Mr. E. T. Jeffery, general superintendent of the Illinois Central Railroad, I was enabled to watch the drivers which that company are using in protecting the lake front of their Chicago property against the inroads of the lake, and to copy both the records and the drawings relating to pile-driving which they have preserved.

I wish to express here my appreciation of the uniform courtesy with which I was treated by all persons connected with this company, and of the many and unusual facilities for making personal investigations and obtaining access to the official files of records and detailed drawings afforded me by Mr. H. A. Kennedy, the master carpenter of the railroad, and Mr. Renshaw, the master machinist of their shops at Weldon.

The company had three drivers—numbered 1, 2, 3—at work all last season. No. 1 was a steam-hammer driver; Nos. 2 and 3, jet drivers of the usual form.

MATERIAL.

No. 1. *Hull.*—The hull is 46 feet long by 24 feet wide by 5 feet deep and is stoutly made and bulkheaded. This has been found to be too short to be used to advantage in pulling old piles.

The leads are of the usual form and height. The weight of hammer is so great, that its line after passing over a sheave at the top of the leads ends in a single block. The line from the power-drum passes under a snatch-block at the foot of the leads ladder, up parallel to the ladder, through the block on the end of the hammer line, and down again to a strong staple in the deck of the flat.

No. 1. *Machinery.*—There is no water jet used with the driver. The hammer is raised and lowered, and the flat moved and piles handled by a twenty-horse power double-cylinder engine with a horizontal boiler. For detail see Plate —.*

The engine was built in 1871. The boiler carries 120 pounds of steam; it has been found to be somewhat too small; the steam-dome is likewise too small to work dry steam, and the result is great loss of fuel, as the supply pump is kept at work forcing cold water into the boiler all the time the engine is at work.

The hammer-drum is coupled to the shaft at will by a gun-metal clutch. See Plate —.*

This is never done while the engine is in motion, the only object of the clutch being to allow the engine to run the winch-heads without disturbing the hammer. The engine is capable of reversing very quickly and easily.

The peculiar feature of the driver is the hammer (plate).* It is composed of two I beams (iron), which form the frame of the whole machine, the leaders for the weight to work in, and at the same time the slides which retain the whole in its position between the wooden leaders of the driver. They are held together at the base by a piece of cast iron, *a*. This is really a hollow frustum of a cone the upper base of the conical opening being 11 inches in diameter, the lower base 15 inches. The top of the pile, "⚒," is cut to a conical shape to fit this opening, and to project into it till the end of the pile is nearly on a level with the upper surface *y*.

The tops of the I beams are fastened directly to the steam cylinder *b*. The weight or hammer proper, *c*, weighs 2,000 pounds.

The action of the machine is as follows:

The pile is raised into its position by the winch-engine; is lowered till it rests on bottom, and is there held by men in the leads. The hammer-drum is now (the engine having stopped) coupled to the shaft by its clutch (Plate —),* the engine started, and the hammer raised an inch or so, one of the deck-hands pulls down on rope "⚒" (see

* Plate not forwarded.

Plate),* thus removing the hammer support. The engine is reversed, and the hammer slowly lowered till the conical top of the pile is fully engaged in the conical cavity in piece *a* (plate*). The top of the pile is thus held perfectly firm and centered in the leads.

The weight *c* is now supported on the head of the pile at *p* by the cylindrical portion *n*, which projects 6 inches below the main body *c*. All is then in condition shown on the plate.

Steam is admitted through the hose H. It passes through the valve *d* into the lower end of the cylinder, and raises the hammer *c* till the inclined plane *e* moves the valve-cam *f*.

This admits steam to an auxiliary cylinder *d* (the valve cylinder), where it presses on the bottom of a peculiar form of D-valve, which it forces to the upper end of the auxiliary cylinder.

The motion of the D-valve cuts off the supply of steam from the bottom of the main cylinder, and opens a very large exhaust port at the same time. No steam is admitted to the upper end of the large cylinder at any time.

The weight of the hammer *c* causes it to fall, drawing the piston-rod and piston down with it. The cylindrical portion *n* strikes the top of the pile *p* and drives the latter down; as soon as the pile begins to sink, the whole frame (hammer cylinder and I beams) is left unsupported and follow it up. When in the fall of *c* the cam lever *f* repassed *e*, the latter moved back to the position shown in the plate, and steam is thus cut off from the auxiliary cylinder, at the same instant a connection through the pipe *g* is made between the two ends of this cylinder. This allows the steam which held the D-valve at the upper end of *d* to press on both top and bottom of the sliding valve. The rate of the latter's fall is so regulated by the cock *h*, which determines the speed of admission of steam to the upper end that the steam is admitted to the lower end of the main cylinder just after the weight *c* has fully delivered its blow. The whole operation is now repeated.

The cock *h* makes it possible to adjust the machine to strike any number of blows a minute, up to eighty. Further, simple adjustments allow the length of stroke to be varied, as well as the force of the blow. This is done by admitting steam to the main cylinder early enough to furnish a steam cushion.

The efficiency of the machine will be fully discussed later.

Nos. 2 and 3. Hull.—These drivers are twins. They are on hulls 46x24x5 feet; the leads are in all respects very similar to those in use under this office, the main difference being that the hammer line is led down under the ladder, round an idle sheave, and thence to the friction-drum.

Nos. 2 and 3. Machinery.—A double-cylinder engine mounted with an upright boiler supplies the power; the water for the jet is supplied by a Nye-pump. Experience with the latter has led to its rejection by the Illinois Central Railroad. It fails to give sufficient pressure to form an efficient jet.

The main difference between these drivers and those under this office is in the form of friction gearing used to raise and drop the hammer. Plate —* gives a general idea of the engine, boiler, and frictions.

This compact arrangement of engine, boiler, and crab on one iron bed plate makes it easy for one man to attend both engine and hammer, and thus do the work of two; the vertical boiler is regarded as objectionable.

In the position shown in the figure, the engine is running under full steam, and the drum is clamped to the shaft, as when raising the hammer. When the latter is at the proper height for the blow desired, handle *a* is moved upward and toward the boiler, handle *b* to a horizontal position, both as indicated by arrows in the figure; *a* releases the friction coupling and lets the hammer fall, *b* shuts off steam from the engine.

In use *a* is held in the master driver's right hand, *b* in his left. A general motion of leaning forward thus starts the engine, and clamps the drum; straightening up drops the hammer and stops the engine; the force applied at *a* to raise 3,600 pounds hammer is slight. By using a double-cylinder engine there is no delay in starting, and steam is used only in doing useful work.

Plate —* shows the details of the friction coupling. The crab consists of a shaft *a* running in the journals *b*, which prevent motion in the direction of the axis of the shaft. A spur-wheel *c* interlocking with a power pinion on the engine shaft, is keyed permanently to "a"; to its face are bolted five oak segments, saturated with some preservative and lubricating preparation. These segments are so attached as to have the grain run radially; their outer ends are turned to a frustum of a cone, and form the male friction surface *d*. The drum *e* and the female friction-surface *f* are cast in one piece, and the whole turns freely on shaft *a*. A spiral spring *g* is employed to hold the male and female surfaces apart, when not intentionally pressed together. A

* Plate not forwarded.

mortise *h* is cut through the shaft at the end of the drum farthest from the female, and through this a plate, *i*, is placed, and held by pins so that it is free to slide in the direction of the shaft axis, but has no other motion with respect to the shaft.

This plate, *i*, bears against a washer, and the latter rests against the end of the drum *j*. A cylindrical hole is bored through the shaft from its end *k*, to the bottom of the mortise in which *i* slides; a bolt, *m*, passes through a stationary nut, *n*, shown also in figure,—at *n*. For 6 inches from its point the thread is turned off, and this portion is inserted in the hole in the shaft, till the point touches "*i*." The action is now plain. Turning the bolt "*m*" to the right forces it to advance toward the drum; this makes the cylindrical part penetrate more deeply into the cylindrical hole in the shaft, and as the point of *m* touches *i*, it forces the latter against the drum, and the latter against the spiral spring *g*, which is thus compressed. The male enters the female and as the motion of *m* is continued the two friction surfaces are pressed so tightly together that the drum is held as firmly to the shaft as if it was keyed. Turning *m* to the left now reverses the entire operation, and the drum is once more loose on the shaft.

The screw-thread on *m* has such a pitch that a movement of 50 degrees is all that is needed to clamp the drum.

The action is perfectly under control at all times, so much so that I have seen the hammer held stationary in the leads, without stopping the engine, by simply lessening the pressure on *a* just enough to let the two friction surfaces slide on each other with the proper relative velocity.

Nos. 1, 2, 3. *Minor details.*—All the hammer rests are placed and removed from deck in the manner shown in Plate —.*

All the chocks have the jaws iron-covered (Plate —),* and are provided with an inch chain about 2 feet long, very firmly stapled to the body of the chock. They are used as follows: A line is led through the chock to the winch, and strained till the flat is in the desired position; a half-hitch is now taken around the line with the chain, and the line thrown off the winch. The strain draws line and chain into the jaws of the chocks, and jams them so that there is no further motion. To free the line it is put to the winch again, and the strain frees the chain from the chock, and all the slack desired is taken in, the line is again thrown off the winch, and is at once held by the chain as before. It would seem that this treatment would be very severe on the lines, but all concurred in the statement that, according to experience at Chicago, lines lasted as long with chain stopping as with ordinary cavils.

PERSONNEL.

The Chicago crew is constituted as follows:

	Per day of 10 hours.
1 foreman of driver	$3 00
2 leader men, each	2 75
1 loft man	2 50
1 engineer	3 00
1 fireman	2 00
2 deck hands, each	2 00
1 axeman	2 00
Total, nine men	17 25

On the drivers while I watched them the engineer handled the hammer as well as the engine, and the foreman was in charge of all three drivers. Two of the crew were at work all the time on the flat loaded with piles, where they were engaged in trimming them to a true conical head to fit the cone in the bottom of the steam hammer, and in removing the bark. According to Mr. Kennedy there has been great difficulty in getting men capable of running the steam-hammer driver up to its real capacity.

NATURE OF WORK.

All three drivers were at work on an extensive shore protection, which consists of two rows of piles (oak) bolted to oak waling pieces. In each row the piles are driven in contact; the clear place between rows is 6 feet. This space is filled in with very large riprap, and the two rows connected together by tie-bolts, 10 feet apart, which pass through the stone at the level of the waling pieces.

* Plate not forwarded.

In 10 feet of water the following material is used in each 100 linear feet:

Piles	140
¾-inch bolts (average length, 24 inches)	100
4 by 4 by ¼ inch washers	200
1¼-inch rods 9½ feet long, with head and nut	20
6 by 6 by ¼ inch washers for the above	40
6 inches by 12 inches by 20 feet oak waling pieces	10
Cubic yards riprap stone	222

The bottom is moderately coarse sand, free from large stones, and with little or no clay to bind it together. At times the driving was done where old pile work or cribs have been formerly placed, and this is the reason of the very small number of piles driven on some days.

There was a feeling of great rivalry between the different master drivers, especially between the jet and steam-hammer men, and these two forms thus received as fine a comparison of their inherent merits as it is possible to obtain where so much of the efficiency of the plant depends on the energy and skill of those who handle it.

The following table, copied from the official records in Mr. Kennedy's office, shows the work done by each driver from August 21 to November 13, 1882, both inclusive:

TABLE VI.—*Chicago pile record.*

Date.	Driver No. 1.				Driver No. 2.				Driver No. 3.			
	No. of piles driven.	Depth driven.	Depth of water.	Locality.	No. of piles driven.	Depth driven.	Depth of water.	Locality.	No. of piles driven.	Depth driven.	Depth of water.	Locality.
		Feet.	*Feet.*			*Feet.*	*Feet.*			*Feet.*	*Feet.*	
Aug. 11	11	14	4	Forty-third street	58	14	8	Kenwood street				
12	44	14	4	do	94	14	8	do	7	14	8	Kenwood street.
13	67	14	2–6	do	45	14	5–10	do	32	14	4–6	Do.
14	52	14	2–3	Thirty-seventh street	29	14	9	Oakland street	25	14	10	Do.
*15												
16	74	14	10	Thirty-fifth street	66	14	10	Kenwood street				
*17												
*18												
*19												
*20												
Sept. 1	12	14	9	Thirty-fifth street	18	14	2	Oakland street	22	14	2	Oakland street.
2												
4	62	14	9	Thirty-fifth street	90	14	2	Oakland street	51	14	10	Kenwood street.
5												
6	44	14	9	Thirty-fifth street	41	14	2	Oakland street				
7	98	14	9	do	92	14	2	do	71	14	10	Forty-fifth street.
8	98	14	9	do	115	14	4	do	71	14	10	Do.
9	8	14	9	do	1	14	4	do	1	14	10	Do.
*11												
*12												
*13												
14	22	14	9	Thirty-fifth street	37	14	4	Oakland street	30	14	10	Forty-fifth street.
15	91	14	9	do	104	14	4	do	79	14	10	Do.
16												
18	37	14	9		38	14	4	Oakland street	41	14	10	Forty-fifth street.
19	100	14	9	Thirty-fifth street	73	14	4	do	93	14	10	Do.
20	105	14	9	do	115	14	4	Forty-third street	74	14	6	Forty-first street.
*21												
*22												
23	45	14	9	Thirty-fifth street	30	14	4	Forty-third street	28	14	6	Forty-first street.
24	34	14	9	do	9	14	4	do	8	14	6	Do.
*25												
*26												
*27												
*28												
*29												
*30												
*Oct. 1												
*2												

*3												
*4												
*5												
6	113	14	9	Thirty-fifth street	87	14	5	Forty-first street				
7	101	14	9	......do	85	14	4	Forty-third street				
9	99	14	9	......do	102	14	4	......do	33	14	6	Forty-first street.
10	66	14	9	......do	29	14	6	Forty-first street	31	14	6	Do.
*11												
*12												
*13												
14	83	14	9	Thirty-fifth street	113	14	4	Forty-third street	97	14	6	Forty-first street.
15	86	14	9	......do	116	14	4	......do	84	14	6	Do.
17	16	20	6	Round House								
18	10	20	6	......do								
19	23	20	6	......do								
20	57	20	6	......do								
21	8	20	6	......do								
23	18	20	6	......do	73	14	6	Forty-first street	65	14	6	Forty-first street.
24												
25	46	20	6	Round House	80	14	6	Forty-first street	92	14	6	Forty-first street.
26	27	14	9	Thirty-fifth street	23	14	6	......do	38	14	6	Do.
27	39	20	6	Round House								
28												
29												
31												
Nov. 1	77	14	9	Thirty-fifth street	80	14	6	Forty-first street	96	14	6	Forty-first street.
2												
3												
4												
6												
8	75	14	9	Thirty-fifth street	74	14	13	Twentieth street	71	14	4	Forty-third street.
9	3	(†)	(†)	(†)	102	14	13	......do	100	14	13	Twentieth street.
10	42	14	9	Thirty-fifth street	67	14	13	......do	60	14	13	Do.
11	65	14	9	......do	66	14	13	......do	58	14	13	Do.
13					67	14	13	......do	64	14	13	Do.

* Stormy.

† Broke down.

The mean number of piles driven in a day by the different drivers are: No. 1, 53.9; No. 2, 66.9; No. 3, 54.4. Nos. 2 and 3 drove some piles in the round-house, which are not recorded. There each pile had to be in exact position, within an error of 6 inches, and was required to be driven 20 feet.

For this work No. 1 was the most efficient, and did a large part of the work. The work was of such a difficult character that it should not be considered with the rest in comparing the two forms of driver. Omitting those days on which No. 1 worked in the round-house (Nos. 2 and 3 being unrecorded when at work there), the following are the means which afford a true comparison: No. 1, 63.2; No. 2, 66.9; No. 3, 54.4 piles a day. The figures speak for themselves. There is little or no advantage in the complicated machinery of the steam hammer. Its average is less than one and greater than the other of two twin jet drivers, which were doing identical work alongside of it.

OPINIONS OF MR. H. A. KENNEDY AND OTHERS.

"The jet drivers on the long average do as much or more than the steam hammer, and this in the class of work now under execution here (Chicago), where the machine-shops of the company are available at any instant.

"The leads last between three and four times as long with the steam hammer as with the drop hammer. A hammer line lasts the steam hammer one month, while it needs replacing about once in five days with the other form. Say it will drive 500 piles on a jet, 3,000 on the steam hammer driver. The flats for both are too broad and short for convenience in pulling old piles.

"The steam hammer leaves the pile-head as good as it was before driving, while the jet drivers injure the head to a considerable extent. On this account, in contracts for wharf work, it is not infrequently stipulated that all piles be driven by steam hammering. For work at a distance from machine-strokes the steam hammer is liable to cause great delays from breakage of some part, and for such work jet drivers are immensely preferred. On a car in land driving the steam hammer is immeasurably superior, as there is much less jar, and the water needed is not excessive. Sixty-five piles a day are expected of every driver in the lake shore protection; if less are driven the matter is looked into. Hard bottom is liable to reduce this number very largely."

Time record.—Bad weather prevented me from seeing the jet drivers at work, except for a part of one morning, in the round-house; here the jet was not used, the tendency of a jetted pile to move laterally in driving prohibiting its use there.

The following observations were made, under average conditions of wind and waves, on the steam hammer:

TABLE VII.—*Steam-hammer observations.*

Number of observation.	Driver in position.	Pile in leads.	Hammer on pile.	Start hammer.	Pile driven.	No. of strokes.	Hammer aloft.	Depth of water.	Length of pile.
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*		*m. s.*	*Feet.*	*Feet.*
73	24 10	25 20	25 40	25 48	27 30	84	.....	7	24
74	29 20	30 30	31 00	31 55	32 55	....	33 30	7	24
75	35 30	36 30	37 20	37 40	39 45	104	40 15	7	24
76	40 45	41 40	42 05	42 20	43 45	63	44 10	7	24
77	44 55	45 30	46 25	46 45	48 10	66	48 30	7	24
78	49 30	50 30	51 00	51 05	51 05	155	54 30	7	24
79	57 55	59 00	59 20	59 50	2 00	129	2 25	7	24
80	3 30	4 30	4 55	5 10	6 40	88	7 20	7	24
81	8 15	9 05	9 40	9 52	11 05	75	11 30	7	24
82	12 20	13 30	14 05	14 12	15 35	79	16 00	7	24
83	17 10	18 40	19 15	19 27	20 50	72	21 15	7	24
84	22 30	25 30	26 20	26 45	29 35	128	30 10	7	24
85	34 45	39 15	39 45	39 55	41 10	72	41 35	7	24
86	42 15	44 15	44 55	45 13	46 40	85	47 05	7	24
87	48 00	49 15	49 35	49 50	52 15	122	52 40	7	24
88	54 00	54 55	55 25	55 30	57 10	77	57 45	7	24
89	58 35	0 05	0 35	0 48	2 50	80	3 15	7	24
90	4 00	5 10	5 40	5 40	7 30	76	7 55	7	24
91	9 00	10 00	10 25	10 42	12 50	60	13 15	7	24
92	19 00	20 15	20 55	21 10	23 10	80	23 35	7	24
93	24 20	25 55	26 30	26 53	29 00	72	29 25	7	24
94	31 30	32 00	32 15	32 25	33 55	69	34 40	7	24
95	27 00	28 30	29 05	29 25	31 10	75	31 35	7	24
96	34 35	35 55	36 10	36 33	37 05	30	37 30	7	24
97	35 20	39 20	39 40	39 52	40 20	25	40 45	7	24
98	41 25	42 22	42 45	43 03	43 33	26	43 55	7	24
99	44 50	45 35	46 10	46 25	46 59	31	47 35	7	24
100	48 25	49 35	50 05	50 20	51 12	42	52 10	7	24
101	52 50	54 30	54 55	55 08	56 37	79	57 05	7	24
102	0 45	2 10	2 35	2 46	3 43	49	4 05	7	24

TABLE VII.—*Steam-hammer observations*—Continued.

Number of observation.	Driver in position.	Pile in leads.	Hammer on pile.	Start hammer.	Pile driven.	No. of strokes.	Hammer aloft.	Depth of water.	Length of pile.
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*		*m. s.*	*Feet.*	*Feet.*
103	4 50	5 55	6 25	6 41	7 13	30	7 35	7	24
104	9 10	10 05	10 30	10 42	11 17	30	11 40	7	24
105	12 25	13 45	14 10	14 35	15 05	27	15 30	7	24
106	16 25	18 10	18 30	18 48	19 23	27	19 45	7	24
107	22 50	23 50	24 15	24 33	25 55	35	26 35	7	24
108	17 00	18 50	19 10	19 19	20 25	33	20 55	7	24

From Table VII Table VIII is obtained, as II was from I.

TABLE VIII.—*Time intervals, &c.*

Number of observation.	Feet driven.	Length of pile.	Depth of water.	Driver in position to pile in leads	Pile in leads to hammer on pile.	Hammer on pile to start hammer.	Pile in leads to pile driven.	Pile driven to hammer aloft.	To put the driver in position.
		Feet.	*Feet.*						
73	14	24	7	70	20	8	2.2	.....	5.2
74	14	24	7	70	30	55	2.4	35	6.2
75	14	24	7	60	50	20	3.3	30	5.2
76	14	24	7	55	25	15	2.1	25	4.2
77	14	24	7	35	55	20	2.7	20	4.6
78	14	24	7	60	30	5	3.6	25	2.3
79	14	24	7	65	30	30	3.0	25	5.6
80	14	24	7	60	25	15	2.2	40	4.8
81	14	24	7	50	35	12	2.0	25	3.1
82	14	24	7	70	35	7	2.2	25	4.8
83	14	24	7	90	35	12	2.2	25	5.3
84	14	24	7	180	50	25	4.1	35	2.2
85	14	24	7	270	30	10	1.9	25	7.5
86	14	24	7	120	40	18	2.4	25	5.8
87	14	24	7	75	20	15	3.0	25	6.0
88	14	24	7	55	30	5	2.3	35	4.6
89	14	24	7	90	30	13	2.7	25	5.4
90	14	24	7	70	30	.....	2.3	25	5.0
91	14	24	7	60	25	17	2.8	25	10.0
92	14	24	7	75	40	15	2.9	25	5.3
93	14	24	7	95	35	23	3.1	25	7.2
94	14	24	7	60	15	10	1.9	45	5.5
95	14	24	7	90	35	20	2.7	25	7.6
96	14	24	7	80	15	23	1.2	25	3.7
97	14	24	7	60	20	12	1.0	25	3.1
98	14	24	7	57	53	18	1.2	20	3.4
99	14	24	7	45	35	15	1.4	30	3.6
100	14	24	7	70	30	15	1.6	58	4.4
101	14	24	7	100	25	13	2.1	26	7.9
102	14	24	7	75	25	11	1.6	22	4.1
103	14	24	7	65	30	16	1.8	22	4.2
104	14	24	7	55	25	12	1.2	23	3.3
105	14	24	7	80	25	25	1.3	25	4.0
106	14	24	7	105	20	18	1.2	22	6.4
107	14	24	7	60	25	18	2.1	30	4.2
108	14	24	7	110	20	9	1.6	30	.....
Mean	14	24	7	80.2	29.7	16.0	2.2	27.4	4.9

The following shows our mean times as compared with the Chicago means:

	Chicago.	Saint Louis.
Feet driven	14.0	13.6
Driver in position to pile in leads	1.3	17.7
Pile in leads to pile driven	2.2	8.7
Depth of water, feet	7	15.5
Length of pile, feet	24	34.8
Current (miles per hour)	0	3–6

The immense difference between the amount of work done at the two localities is caused almost entirely by the current. In the river it is a continual struggle both to hold the flat in place and the pile in the leads; at Chicago there is no strain on the lines holding the flat, which is disturbed only by wind and waves, and two men hold the pile in the leads with a single light line, till the hammer is placed on it.

The downward velocity of the pile was no greater at Chicago than here, as numerous measurements proved, but it was continuous; while here stoppages are constantly occurring, from the time the pile starts till it stops.

PART III.—POSSIBLE ECONOMY OF USING STEAM-HAMMER DRIVERS ON THE MISSISSIPPI.

The cost of the Illinois Central Railroad driver of this form was: steam hammer $1,593.50 (weight 7,500 pounds); license to build and use the same, $500; hull, $2,000; boiler and engine, $2,333.59; total, $6,427.09. The weight of this size of hammer is too great for cottonwood piles; the second size, weighing one-half as much, would be what is required. Its cost, free of license if obtained direct from the manufactory, is $875. The only possible saving would be in lessening the time now spent in actual driving, and this, with our present form, is but a small fraction of that needed per pile. The difference in cost of the present hammer ($80) and the steam hammer ($875) is $795, and under the most favorable circumstances it would take a long time to pay for itself.

The more simple the machinery used, the greater is the chance of real efficiency, when the work is carried on, as under this office, at a distance from machine-shops. If any saving is to be made by extensive change of plant, it must be found in some method of driving more than one pile from each position of the flat, thus eliminating partly the slow and vexatious changes of position in severe currents.

PART IV.—VELOCITY OF PENETRATION AS A FUNCTION OF THE PENETRATION OBTAINED.

It added but little labor to record the time at which each pile had penetrated 2 feet, 4 feet, 6 feet, &c. While I was studying other more important elements involved in practical pile-driving, I therefore incidentally made the observations shown in columns eighteen to twenty-five, inclusive, in Table 1, page 18, thinking that in connection with further experiments they might throw some light on the important question of the quantity of water needed for the most efficient work with a combined jet and hammer driver.

Table IX shows the total number of seconds required by each pile from the time it was in the leads till it had penetrated the number of feet at the head of each column. In this table no allowance is made for unusual delays, they are all considered as part of the time occupied in driving; in other words, the table gives the true and entire history of the downward movement of each pile.

TABLE IX.—*Seconds from "pile in leads," till pile has penetrated.*

No. of observation.	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.	No. of observation.	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.
1..	15	60	80	180	240	300	.....	.....	16..	180	210	250	275	290	312	325	350
2..	90	120	155	175	390	465	630	.....	17..	200	220	780	900	910	925	990	995
3..	315	435	480	590	715	775	810	.....	18..	275	283	298	330	345	360	365	420
4..	90	140	155	173	230	390	435	510	19..	60	70	80	150	205	206	210	300
5..	275	370	470	485	505	515	540	.....	20..	13	14	15	30	50	60	75	95
6..	165	273	310	432	600	.....	.....	.....	21..	390	400	435	440	470	495	520	580
7..	60	330	335	340	600	630	720	.....	22..	110	258	290	345	360	420	430	.....
8..	330	400	415	440	470	490	540	.....	23..	150	220	235	260	295	320	470	595
9..	240	255	350	390	450	510	840	.....	24..	355	375	440	455	515	590	630	.....
10..	70	94	107	135	170	225	270	.....	25..	210	217	225	280	540	575	690	.....
11..	290	305	375	400	460	530	575	1,225	26..	200	210	500	615	620	630	690	710
12..	320	330	345	375	405	410	480	550	27..	360	500	505	545	558	640	670	760
13..	180	285	450	465	615	840	.....	.....	28..	130	135	160	220	265	360	.....	.....
14..	370	380	630	635	673	690	715	735	29..	125	135	145	270	275	280	340	400
15..	370	375	450	460	810	925	.....	.....	30..	480	495	540	660	720	.....	.....	.....

TABLE IX.—*Seconds from "pile in leads," till pile has penetrated*—Continued.

No. of observation.	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.	No. of observation.	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.
31..	45	140	240	360	.....	.....	.....	.....	52..	150	165	160	195	215	235	270	330
32..	395	495	540	605	720	840	.....	.....	53..	150	210	235	285	375	495	.....	.....
33..	210	235	435	450	460	622	680	.....	54..	120	175	200	260	335	385	.....	.....
34..	420	590	590	615	705	765	855	.....	55..	60	110	170	240	315	.....	.....	.....
35..	90	90	90	240	245	290	295	.....	56..	135	185	215	230	270	315	.....	.....
36..	210	225	240	540	660	900	.....	.....	57..	120	150	255	380	490	.....	.....	.....
37..	60	140	190	250	250	310	465	.....	58..	60	130	155	180	360	480	635	.....
38..	60	90	150	240	270	350	390	.....	59..	30	60	120	140	165	200	.....	.....
39..	55	70	100	135	195	230	300	375	60..	30	40	65	90	165	225	285	.....
40..	85	95	100	135	155	180	195	210	61..	70	90	150	160	165	175	200	270
41..	85	90	120	.....	.....	.....	.....	.....	62..	.....	.....	.....	.....	.....	.....	.....	.....
42..	135	140	150	200	230	250	270	280	63..	.....	.....	.....	.....	.....	.....	.....	.....
43..	85	130	240	260	275	280	.....	.....	64..	.....	.....	.....	.....	.....	.....	.....	.....
44..	60	115	175	190	210	480	.....	.....	65..	.....	.....	.....	.....	.....	.....	.....	.....
45..	255	300	310	325	410	460	550	.....	66..	.....	.....	.....	.....	.....	.....	.....	.....
46..	45	45	50	60	100	135	.....	.....	67..	.....	.....	.....	.....	.....	.....	.....	.....
47..	15	85	100	190	270	390	590	720	68..	.....	.....	.....	.....	.....	.....	.....	.....
48..	195	215	270	272	315	335	340	360	69..	145	170	183	225	250	285	300	.....
49..	100	160	215	370	585	900	.....	.....	70..	.....	.....	.....	.....	.....	.....	.....	.....
50..	30	32	34	90	120	135	210	240	71..	30	32	70	110	240	405	540	.....
51..	5	7	10	15	140	150	180	260	72..	120	150	130	185	300	540	.....	.....

This table is shown graphically on Plate VII, where the co-ordinate axes represent, the vertical the penetration in feet, the horizontal the time in seconds occupied in attaining the corresponding penetrations. Examining the plate, the following peculiarities are seen:

1. The long time taken in penetrating the first 2 feet. This arises from the fact that the pile is still held by the log-chain line, and thus penetrates only as fast as this line is slacked off. Again, the hammer is not yet on the pile, and it is urged downward only by its own weight. The time to descend till it touches bottom is also included.

2. The irregularity of the movement. The pile usually goes down by sudden jumps, as though the jet made a hole not quite large enough to admit the pile at first, but that the washing away of the sides at last let it fall to the bottom of the hole, or as if the bottom were composed of thin hard layers, separated by relatively much thicker ones of soft alluvion. Both are probably active agents, contributing to the same result.

3. The pile often penetrates the last 2 feet in as little time as any other interval of like amount.

This is explained by the fact that the piles are not intended to support a weight, as in a foundation, but only to resist a tendency to be forced over by the current, drift, and ice. This does not necessitate driving till the pile goes hard, but only to force it deep enough into the soil to prevent lateral movement. Fourteen feet is the distance usually required; in soft bottom, 16 feet or more is the depth driven; in hard bottom 12 feet is ample.

The driving is usually stopped after a penetration of 12 feet has been obtained, first, when the head of the pile (cottonwood) becomes so much battered up as to form an elastic cushion, so that the hammer does not strike a fair blow; second, when the pile penetrates so slowly that it is wasting time to try to force it farther; third, when the head of the pile is at the level desired, provided the depth driven in this last case is sufficient in the bottom there existing to secure stability.

4. Many excessive delays. These are shown on the plot by nearly horizontal portions of a pile's course, preceded and followed by portions which are nearly vertical. They generally indicate that work was temporarily suspended to adjust toggle, lines, &c.

5. The sudden descent shown in almost every pile from 2 feet to 6 feet or 8 feet. This is caused by the first placing of the hammer on the pile.

It is plain, inasmuch as some piles (in hard bottom) were driven only 10 feet, and others (in soft bottom) 16 feet, that the simple means of the columns of Table IX would express no law.

If all the piles had been driven (as in foundations) till the velocity of penetration was reduced to some very small value, the complete method of combining the obser-

vations to derive the law of velocity of penetration as a function of the penetration attained would be as follows:

1. Find the absolute time each pile occupied in penetrating the successive intervals of 2 feet.

2. Throw out all times that were marked in the field as vitiated by toggle or other delays.

3. Find the fractional part of the whole time occupied by each pile in real penetration, which was used in penetrating the first 2, 4, 6, 8 feet, &c. The resulting fractions will be called "time fractions."

4. Find the fractional part of the entire penetration of each pile which corresponds to 2, 4, 6, 8 feet, &c. The resulting fractions will be called "distance fractions."

5. Take the mean of all the time fractions (above defined) which correspond to equal distance fractions (above described).

For clearer appreciation of the above, consider the case of two piles, one driven "a" feet, the second "a" × "a" feet.

The time fractions obtained by above head, 3 correspond in both to 2 feet, 4 feet, 6 feet, &c., but $\frac{2\text{ feet}}{a\text{ feet}}$, $\frac{4\text{ feet}}{a\text{ feet}}$, $\frac{6\text{ feet}}{a\text{ feet}}$ are larger fractions than $\frac{2\text{ feet}}{a \times a\text{ feet}}$, $\frac{4\text{ feet}}{a \times a\text{ feet}}$, $\frac{6\text{ feet}}{a \times a\text{ feet}}$, &c., therefore the time fractions do not correspond to equal portions of the entire penetration in the two cases, and should, therefore, not be combined into one mean.

Piles driven 16 feet would thus determine the points on the curve corresponding to one-eighth, two-eighths, three-eighths, &c.; those driven 14 feet, those corresponding to one-seventh, two-sevenths, three-sevenths, &c.; those driven 12 feet, those corresponding to one-sixth, two-sixths, three-sixth, &c.; those driven 10 feet, those corresponding to one-fifth, two-fifths, three-fifths, &c., and so on. These operations are shown in the following tables:

TABLE X.—*Absolute time intervals.*

No. of observation.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	No. of observation.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.
1	15	45	20	100	60	60	.....	.....	37	60	80	50	60	0	60	155	.....
2	90	30	35	20	30	75	165	.....	38	60	30	60	90	30	80	40	.....
3	315	120	45	110	125	60	35	.....	39	55	15	30	35	60	35	70	75
4	90	50	15	18	57	160	45	75	40	85	10	5	35	20	25	15	15
5	275	95	100	15	20	10	25	.....	41	85	5	30	.....	.....	.....	.....	.....
6	165	108	37	122	168	.....	.....	.....	42	135	5	10	50	30	20	20	10
7	60	270	5	5	.....	30	190	.....	43	85	45	110	20	15	5	.....	.....
8	330	70	15	25	30	20	50	.....	44	60	55	55	20	20	270	.....	.....
9	240	15	95	40	60	60	.....	.....	45	255	45	10	15	.....	50	90	.....
10	70	24	13	28	35	55	45	.....	46	45	0	5	10	40	35	.....	.....
11	290	15	70	25	60	70	45	.....	47	15	70	15	90	.....	120	200	130
12	320	10	15	30	30	5	70	70	48	195	20	55	2	43	20	5	20
13	180	105	165	15	.....	225	.....	.....	49	100	60	55	.....	215	325	.....	.....
14	370	10	.....	5	38	17	25	20	50	30	2	2	56	30	15	75	30
15	370	5	75	10	.....	115	.....	.....	51	5	2	3	5	.....	10	30	80
16	180	30	40	25	15	22	13	25	52	150	5	5	35	20	20	35	60
17	200	20	.....	120	10	15	65	5	53	150	60	25	50	90	120	.....	.....
18	275	8	15	32	15	15	5	55	54	120	55	25	60	75	50	.....	.....
19	60	10	10	70	55	1	4	90	55	60	50	60	70	75	.....	.....	.....
20	13	1	1	15	20	10	15	20	56	135	50	30	15	40	45	.....	.....
21	390	10	35	5	30	25	30	61	57	120	30	105	125	110	.....	.....	.....
22	110	148	32	55	15	60	10	.....	58	60	70	25	25	.....	150	125	.....
23	150	70	15	25	35	25	150	125	59	30	30	60	20	25	35	.....	.....
24	355	20	65	15	60	75	40	.....	60	30	10	25	25	75	60	60	.....
25	210	7	8	55	.....	35	175	.....	61	70	20	60	10	5	10	25	70
26	200	10	.....	115	5	10	60	20	62	.....	.....	.....	.....	.....	.....	.....	.....
27	360	140	5	40	13	82	30	90	63	.....	.....	.....	.....	.....	.....	.....	.....
28	130	5	25	60	45	95	.....	.....	64	.....	.....	.....	.....	.....	.....	.....	.....
29	125	10	10	125	5	5	60	60	65	.....	.....	.....	.....	.....	.....	.....	.....
30	480	15	45	.....	60	.....	.....	.....	66	.....	.....	.....	.....	.....	.....	.....	.....
31	45	95	100	120	.....	.....	.....	.....	67	.....	.....	.....	.....	.....	.....	.....	.....
32	395	100	45	65	115	120	.....	.....	68	.....	.....	.....	.....	.....	.....	.....	.....
33	240	25	.....	15	10	.....	58	.....	69	145	25	13	42	25	35	15	.....
34	420	170	0	25	90	60	90	.....	70	90	30	120	10	20	75	.....	.....
35	90	0	0	150	5	45	5	.....	71	30	2	38	40	130	165	135	.....
36	210	15	15	.....	120	240	.....	.....	72	120	30	80	55	15	240	.....	.....

TABLE XI.—*Time fractions.*

No. of observation.	2 minutes.	4 minutes.	6 minutes.	8 minutes.	10 minutes.	12 minutes.	14 minutes.	16 minutes.	No. of observation.	2 minutes.	4 minutes.	6 minutes.	8 minutes.	10 minutes.	12 minutes.	14 minutes.	16 minutes.
1	.0500	.2000	.2667	.6001	.8000	1.0000	.....	.....	38	.1538	.2230	.3845	.6152	.6921	.8973	1.0000	.....
2	.2023	.2698	.3485	.3935	.4610	.6297	1.0000	.....	39	.1466	.1866	.2660	.3599	.5190	.6133	.8000	1.0000
3	.3880	.5373	.5929	.7279	.8823	.9566	1.0000	.....	40	.4046	.4522	.4760	.6427	.7378	.8569	.9284	1.0000
4	.1766	.2745	.3049	.3402	.4519	.7652	.8535	1.0000	41	.7080	.7498	1.0000	.....	.....	.....	.....	.....
5	.5093	.6851	.8705	.8983	.9354	.9840	1.0000	.....	42	.4808	.4987	.5845	.7133	.8207	.8924	.9641	1.0000
6	.2748	.4547	.5165	.7199	1.0000	.....	.....	.....	43	.3034	.4641	.8567	.9283	.9829	1.0000	.....	.....
7	.1072	.5894	.5983	.6072	.....	.6606	1.0000	.....	44	.1250	.2396	.3542	.3959	.4376	1.0000	.....	.....
8	.6109	.7406	.7684	.8146	.8702	.9073	1.0000	.....	45	.5433	.6451	.6666	.6989	.....	.8014	1.0000	.....
9	.4706	.5000	.6803	.7647	.8823	1.0000	.....	.....	46	.3344	.3344	.3688	.4529	.7495	1.0000	.....	.....
10	.2504	.3483	.3905	.5003	.6298	.8334	1.0000	.....	47	.0234	.1330	.1564	.2970	.....	.4845	.7970	1.0000
11	.5043	.5304	.6521	.6956	.7999	.9217	1.0000	.....	48	.5417	.5973	.7501	.7557	.8750	.9305	.9444	1.0000
12	.5821	.6000	.6276	.6822	.7368	.7459	.8734	1.0000	49	.1324	.2119	.2848	.....	.5095	1.0000	.....	.....
13	.2609	.4131	.6523	.6739	.....	1.0000	.....	.....	50	.1250	.1333	.1413	.3749	4999	.5624	.8750	1.0000
14	.7630	.7836	.....	.7939	.8722	.9073	.9588	1.0000	51	.0362	.0510	.0732	.1104	.....	.1847	.4071	1.0000
15	.6434	.6521	.7825	.7990	.....	1.0000	.....	.....	52	.4550	.4702	.4854	.5914	.6519	.7123	.8182	1.0000
16	.5140	.5997	.7140	.7854	.8282	.8911	.9284	1.0000	53	.3033	.4244	.4747	.5753	.7575	1.0000	.....	.....
17	.4597	.5057	.....	.7815	.8046	.8391	.9887	1.0000	54	.3119	.4548	.5196	.6754	.8702	1.0000	.....	.....
18	.6546	.6737	.7094	.7856	.8213	.8570	.8690	1.0000	55	.1905	.3494	.5399	.7620	1.0000	.....	.....	.....
19	.2000	.2430	.2666	.4999	.6831	.6867	.7001	1.0000	56	.4285	.5874	.6827	.7303	.8573	1.0000	.....	.....
20	.1368	.1473	.1578	.3156	.5260	.6314	.7894	1.0000	57	.2449	.3061	.5204	.7757	1.0000	.....	.....	.....
21	.6653	.6867	.7464	.7549	.8051	.8468	.8970	1.0000	58	.1319	.2857	.3405	.3953	.....	.7248	1.0000	.....
22	.2559	.6002	.6747	.8026	.8374	.9769	1.0000	.....	59	.1500	.3000	.5999	.6999	.8249	1.0000	.....	.....
23	.2523	.3701	.3953	.4373	.4962	.5381	.7903	1.0000	60	.1052	.1403	.2280	.3157	.5788	.7894	1.0000	.....
24	.5636	.5954	.6987	.7225	.8187	.9367	1.0000	.....	61	.2594	.3335	.5558	.5929	.6114	.6485	.7408	1.0000
25	.4285	.4428	.4591	.5714	.....	.6429	1.0000	.....	62	.....	.....	.....	.....	.....	.....	.....	.....
26	.4762	.5000	.....	.7738	.7857	.8095	.9524	1.0000	63	.....	.....	.....	.....	.....	.....	.....	.....
27	.4732	.6573	.6639	.7165	.7337	.8418	.8815	1.0000	64	.....	.....	.....	.....	.....	.....	.....	.....
28	.3614	.3753	.4448	.6115	.7365	1.0000	.....	.....	65	.....	.....	.....	.....	.....	.....	.....	.....
29	.3126	.3376	.3626	.6752	.6876	.7006	.8500	1.0000	66	.....	.....	.....	.....	.....	.....	.....	.....
30	.7998	.8248	.8999	.....	1.0000	.....	.....	.....	67	.....	.....	.....	.....	.....	.....	.....	.....
31	.1250	.3886	.6666	1.0000	.....	.....	.....	.....	68	.....	.....	.....	.....	.....	.....	.....	.....
32	.4699	.5890	.6426	.7201	.8570	1.0000	.....	.....	69	.4831	.5662	.6095	.7495	.8329	.9498	1.0000	.....
33	.6604	.7891	.....	.7863	.8177	.....	1.0000	.....	70	.2608	.3477	.6955	.7246	.7825	1.0000	.....	.....
34	.4911	.6899	.6899	.7191	.8244	.8947	1.0000	.....	71	.0556	.0593	.1297	.2038	.4445	.7500	1.0000	.....
35	.3052	.3052	.3052	.8138	.8307	.9832	1.0000	.....	72	.2218	.3773	.4252	.5273	.5562	1.0000	.....	.....
36	.3499	.3749	.3999	.....	.5999	1.0000	.....	.....	Mean.	.3482	.4356	.5179	.6309	.7458	.8252	.9192	1.000
37	.1290	.3010	.4085	.5375	.5375	.6660	1.0000	.....									

TABLE XII.—*Distance fractions.*

Depth driven.	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.
16 feet	.125	.250	.375	.500	.625	.750	.875	1.000
14 feet	.143	.286	.429	.572	.715	.857	1.000	.....
12 feet	.167	.333	.500	.667	.833	1.000	.....	.....
10 feet	.200	.400	.600	.800	1.000	.....	.....	.....
8 feet	.250	.500	.750	1.000	.....	.....	.....	.....
6 feet	.333	.667	1.000	.....	.....	.....	.....	.....
4 feet	.500	1.000	.....	.....	.....	.....	.....	.....
2 feet	1.000	.....	.....	.....	.....	.....	.....	.....
0 feet	.....	.....	.....	.....	.....	.....	.....	.....

TABLE XIII.—*Corresponding time and distance fractions.*

No. of observations.	Distance fractions.																					
	.125	.143	.167	.200	.250	.286	.333	.375	.400	.429	.500	.572	.600	.652	.667	.715	.750	.800	.833	.857	.875	1.000
1			.0500				.2000				.2667				.6001				.8000			1.0000
2		.2023				.2698				.3485		.3935				.4610				.6297		1.0000
3		.3890				.5373				.5929		.7279				.8823				.9566		1.0000
4	.1766				.2745			.3040			.3402			.4519			.7652				.8535	1.0000
5		.5003				.6851				.8705		.8983				.9354				.9940		1.0000
6				.2748					.4547				.5165					.7199				1.0000
7		.1072				.5894				.5983		.6072								.6606		1.0000
8		.6109				.7406				.7684		.8146				.8702				.9073		1.0000
9			.4706				.5000				.6863				.7647				.8823			1.0000
10		.2504				.3483				.3965		.5003				.6298				.8334		1.0000
11		.5043				.5304				.6521		.6956				.7999				.9217		1.0000
12	.3821				.6003			.6276			.6822			.7368			.7459				.8734	1.0000
13			.2609				.4131				.6523				.6739							1.0000
14	.7630				.7836						.7939			.8722			.9073				.9588	1.0000
15			.0434				.6521				.7825				.7999							1.0000
16	.5140				.5997			.7140			.7854			.8282			.8911				.9284	1.0000
17	.4597				.5057						.7815			.8046			.8391				.9887	1.0000
18	.6546				.6737			.7094			.7856			.8213			.8570				.8690	1.0000
19	.2000				.2333			.2666			.4999			.6831			.6867				.7001	1.0000
20	.1368				.1473			.1578			.3156			.5260			.6314				.7894	1.0000
21	.6053				.6867			.7464			.7549			.8051			.8468				.8970	1.0000
22		.2559				.6002				.6747		.8026				.8374				.9769		1.0000
23	.2523				.3701			.3953			.4373			.4962			.5381				.7963	1.0000
24		.5636				.5954				.6987		.7225				.8187				.9367		1.0000
25		.4285				.4428				.4591		.5714								.6429		1.0000
26	.4762				.5000						.7738			.7857			.8095				.9524	1.0000
27	.4732				.6573			.6639			.7165			.7337			.8418				.8815	1.0000
28			.3614				.3753				.4448				.6115				.7385			1.0000
29	.3126				.3376			.3626			.6752			.6876			.7000				.8500	1.0000
30				.7998					.8248				.8999									1.0000
31					.1250						.3886						.6666					1.0000
32			.4699				.5890				.6426				.7201				.8570			1.0000
33		.0604				.7391						.7863				.8177						1.0000
34		.4911				.6899				.6899		.7191				.8244				.8947		1.0000
35		.3052				.3052				.3052		.8138				.8307				.9832		1.0000
36			.3499				.3749				.3999								.5999			1.0000
37		.1290				.3010				.4085		.5375				.5375				.6660		1.0000
38		.1538				.2307				.3845		.6152				.6921				.8973		1.0000
39	.1466				.1866			.2660			.2599			.5199			.6133				.8000	1.0000
40	.4046				.4522			.4760			.6427			.7378			.8569				.9284	1.0000
41							.7080								.7498							1.0000

TABLE XIII.—*Corresponding time and distance fractions*—Continued.

No. of observations.	Distance fractions.																					
	.125	.143	.167	.200	.250	.286	.333	.375	.400	.429	.500	.572	.600	.652	.667	.715	.750	.800	.833	.857	.875	1.000
42	.4808				.4987			.5345			.7133			.8207			.8924				.9641	1.0000
43			.3034				.4641				.8567				.9263				.9829			1.0000
44			.1250				.2396				.3542				.3959				.4376			1.0000
45		.5483				.6451			.6666		.6989									.8014		1.0000
46			.3344				.3344				.3688				.4529				.7495			1.0000
47	.0234				.1330			.1564			.2970						.4845				.7970	1.0000
48	.5417				.5973			.7501			.7557			.8750			.9305				.9444	1.0000
49			.1324				.2119				.2848								.5695			1.0000
50	.1250				.1333			.1416			.3749			.4999			.5624				.8750	1.0000
51	.0362				.0510			.0732			.1104						.1847				.4071	1.0000
52	.4550				.4702			.4854			.5914			.6519			.7123				.8182	1.0000
53			.3033				.4244				.4747				.5753				.7575			1.0000
54			.3119				.4548				.5196				.6754				.8702			1.0000
55				.1905					.3494				.5399					.7620				1.0000
56			.4285				.5874				.6827				.7303				.8573			1.0000
57				.2449					.3061				.5204					.7757				1.0000
58		.1319				.2857				.3405		.3953								.7248		1.0000
59			.1500				.3000				.5999				.6999				.8249			1.0000
60		.1052				.1403				.2280		.5157				.5788				.7894		1.0000
61	.2594				.3335			.5558			.5929			.6114			.6485				.7408	1.0000
62																						
63																						
64																						
65																						
66																						
67																						
68																						
69		.4831				.5662				.6095		.7495				.8329				.9498		1.0000
70			.2608				.3477				.6955				.7246				.7825			1.0000
71		.0556				.0593				.1297		.2038				.4445				.7500		1.0000
72			.2218				.2773				.4252				.5273				.5562			1.0000
Mean	.3700	.3447	.3046	.3750	.4065	.4651	.4141	.4415	.4837	.5169	.5577	.6285	.6442	.6975	.6644	.7371	.7223	.7525	.7509	.8393	.8458	1.0000

Table XIII is shown graphically on Plate VIII, Fig. 2. The irregularity of the mean curve there plotted shows either that there is no law which is sufficiently marked to be shown by such a limited number of observations, or that the assumptions made for purposes of discussion were not in accordance with the real facts. That the latter is the case is, I think, indicated by the smooth curve obtained under the following assumptions, though much of the regularity may be due to the fact that each point is determined by the mean of nearly seventy-two observations.

That the piles were not driven in equally resisting bottom is well known, but the reason that many of them were not driven the full depth of 16 feet was that the master driver had struck too heavy blows for the head of the cottonwood pile to stand, and the head had thus been utterly destroyed before the pile was fully driven. On this account it would seem that a better way to discuss the observations would be to assume that the ratio of the velocity of penetration at the 2-foot depth to that at 4 feet is constant, although the absolute values of these velocities are different for all varieties of bottom; and to extend this law to 6 feet, 8 feet, 10 feet, &c.

In other words, assume that *a* represents the velocity when a penetration of 2 feet is attained, *ba* that at 4 feet, *ca* that at 6 feet, &c., for any given locality; then at any other locality where the velocity at 2 feet is *a* feet, that at 4 feet will be *ba* feet, that at 6 feet *ca* feet, &c., in which *b*, *c*, &c., have the same values as before. Making these assumptions, the object is to obtain the values of *b*, *c*, &c., from the observations.

Under this hypothesis the difference in the hardness of the bottom at different places makes it necessary, as before, to construct a table of "time fractions;" but as the ratio of velocity at 2 feet to that at 4 feet, 6 feet, 8 feet, &c., is what is desired, the time fractions must be combined according to the absolute penetration in feet to which they correspond instead of combining as before according to corresponding "distance fractions."

Table XI is then already in the proper shape for plotting. Plate VI, Fig. 1, this table, plotted, shows very clearly some peculiar features of the history of the mean pile. The slow descent for the first 2 feet is shown as before, then the rapid descent from 2 feet to 6 feet, which is caused by first placing the hammer on the pile. From 6 feet to 10 feet the penetration is less rapid, as the hammer is still at rest, and acts only as dead weight. From 10 feet on the penetration is again more rapid, as by this time the hammer is fairly in action.

The numbers actually shown by this mean curve are almost exactly those pointed out by the means of a number of observations I took to determine the time at which the above changes in the manipulation of the pile takes place.

The changes in the values of *b*, *c*, &c., are so slight that it is practically correct to state that for the depths the piles are driven here there is no appreciable difference in their rate of penetration from the start till they are at their final place of rest. Plate V shows that with many piles the resistance does increase to a marked extent, but taking the long average the last 2 feet are driven in just about the time needed for any other 2 feet.

Table XIV, showing the fractional part of the entire time occupied in penetrating each individual 2-foot interval, is added as of possible interest; it shows the irregularities for single piles more plainly than Table XI.

TABLE XIV.—*Time fractions for individual 2-feet intervals.*

No. of observations.	First 2 feet.	Second 2 feet.	Third 2 feet.	Fourth 2 feet.	Fifth 2 feet.	Sixth 2 feet.	Seventh 2 feet.	Eighth 2 feet.	No. of observations.	First 2 feet.	Second 2 feet.	Third 2 feet.	Fourth 2 feet.	Fifth 2 feet.	Sixth 2 feet.	Seventh 2 feet.	Eighth 2 feet.
1	.0500	.1500	.0667	.3334	.1999	.2000	.....	.....	37	.1290	.1420	.1075	.1290	.0000	.1291	.3334	.....
2	.2023	.0675	.0787	.0450	.0675	.1687	.3703	.....	38	.1538	.0769	.1538	.2307	.0769	.2052	.1027	.....
3	.3890	.1483	.0556	.1358	.1544	.0743	.0434	.....	39	.1466	.0400	.0800	.0933	.1600	.0934	.1867	.2000
4	.1766	.0979	.0294	.0353	.1117	.3133	.0883	.1465	40	.4046	.0476	.0238	.1667	.0951	.1191	.0715	.0716
5	.5003	.1758	.1854	.0278	.0371	.0586	.0060	.....	41	.7080	.0418	.2502	.....	.....	.....	.....	.....
6	.2748	.1799	.0618	.2034	.2801	.....	.....	.....	42	.4808	.0179	.0358	.1788	.1074	.0717	.0717	.0359
7	.1072	.4822	.0089	.0089	.....	.0534	.3394	.....	43	.3034	.1607	.3926	.0716	.0537	.0180	.....	.....
8	.6109	.1297	.0278	.0462	.0556	.0371	.0927	.....	44	.1250	.1146	.1146	.0417	.0417	.5624	.....	.....
9	.4706	.0294	.1863	.0784	.1176	.1177	.....	.....	45	.5483	.0968	.0215	.0323	.....	.1075	.1936	.....
10	.2594	.0889	.0482	.1038	.1295	.2036	.1666	.....	46	.3344	.0000	.0344	.0741	.2966	.2595	.....	.....
11	.5043	.0261	.1217	.0435	.1043	.1218	.0783	.....	47	.0234	.1096	.0234	.1406	.....	.1875	.3125	.2030
12	.5821	.0182	.0273	.0546	.0546	.0091	.1275	.1276	48	.5417	.0556	.1528	.0056	.1193	.0555	.0139	.0556
13	.2609	.1522	.2392	.0216	.....	.3261	.....	.....	49	.1324	.0795	.0729	.....	.2847	.4305	.....	.....
14	.7630	.0200	.....	.0103	.0783	.0351	.0515	.0412	50	.1250	.0083	.0083	.2333	.1250	.0625	.3126	.1250
15	.6434	.0087	.1304	.0174	.....	.2001	.....	.....	51	.0362	.0148	.0222	.0372	.....	.0743	.2224	.5929
16	.5140	.0857	.1143	.0714	.0428	.0629	.0373	.0716	52	.4550	.0152	.0152	.1060	.0605	.0604	.1059	.1818
17	.4597	.0460	.....	.2758	.0231	.0345	.1496	.0113	53	.3033	.1211	.0508	.1006	.1822	.2425	.....	.....
18	.6546	.0191	.0357	.0762	.0357	.0357	.0120	.1310	54	.3119	.1429	.0648	.1558	.1948	.1298	.....	.....
19	.2000	.0333	.0333	.2333	.1832	.0036	.0134	.2999	55	.1905	.1589	.1905	.2221	.2380	.....	.....	.....
20	.1308	.0105	.0105	.1578	.2104	.1054	.1580	.2106	56	.4285	.1589	.0953	.0476	.1270	.1427	.....	.....
21	.0653	.0214	.0597	.0085	.0502	.0417	.0502	.1030	57	.2449	.0612	.2143	.2553	.2243	.....	.....	.....
22	.2359	.3443	.0745	.1279	.0348	.1395	.0231	.....	58	.1319	.1538	.0548	.0548	.....	.3295	.2752	.....
23	.2523	.1178	.0252	.0420	.0589	.0419	.2522	.2097	59	.1500	.1500	.2999	.1000	.1250	.1751	.....	.....
24	.5036	.0318	.1033	.0238	.0952	.1190	.0635	.....	60	.1052	.0351	.0877	.0877	.2631	.2106	.2106	.....
25	.4285	.0143	.0163	.1123	.....	.0715	.3571	.....	61	.2594	.0741	.2223	.0371	.0185	.0371	.0923	.2592
26	.4762	.0238	.....	.2738	.0119	.0238	.1420	.0476	62	.....	.....	.....	.....	.....	.....	.....	.....
27	.4732	.1841	.0066	.0526	.0172	.1081	.0397	.1185	63	.....	.....	.....	.....	.....	.....	.....	.....
28	.3614	.0139	.0695	.1667	.1250	.2635	.....	.....	64	.....	.....	.....	.....	.....	.....	.....	.....
29	.3126	.0250	.0250	.3126	.0124	.0124	.1500	.1500	65	.....	.....	.....	.....	.....	.....	.....	.....
30	.7998	.0250	.0751	.....	.1001	.....	.....	.....	66	.....	.....	.....	.....	.....	.....	.....	.....
31	.1250	.2636	.2780	.3334	.....	.....	.....	.....	67	.....	.....	.....	.....	.....	.....	.....	.....
32	.4699	.1191	.0536	.0775	.1369	.1430	.....	.....	68	.....	.....	.....	.....	.....	.....	.....	.....
33	.0604	.0787	.....	.0472	.0314	.....	.1823	.....	69	.4831	.0831	.0433	.1460	.0834	.1169	.0502	.....
34	.4911	.1988	.0000	.0292	.1053	.0703	.1053	.....	70	.2608	.0869	.3478	.0291	.0579	.2175	.....	.....
35	.3052	.0000	.0000	.5086	.0169	.1525	.0168	.....	71	.0556	.0037	.0704	.0741	.2407	.3055	.2500	.....
36	.3499	.0250	.0250	.....	.2000	.4001	.....	.....	72	.2218	.0555	.1479	.1021	.0289	.4438	.....	.....

PART V.—PROJECT FOR A MULTIPLE-LEADS DRIVER.

Table V, page 28, shows that in driving 20,000 piles $14,255.94 were spent in placing the pile-drivers in position, and by this is meant the change from the position of one pile to the next, and no account is taken of the long moves from one line to another. All this time is absolutely lost as far as any advantage is concerned, and some means by which it can be shortened or avoided is most desirable.

The most practicable and at the same time least expensive method seems to be some arrangement by which putting the flat once in position shall enable the engine to drive several piles.

The object to be obtained is to devise a driver which shall drive the greatest possible number of piles at each position, and still be at least as easy to put in place as the present form.

With the idea of testing the practicability of handling a large flat in severe currents, I tried the experiment of lashing three pile-drivers together, and driving all one day in a current of 5¼ miles an hour in a depth of water of 19 feet. The area of the flat thus joined was 60 feet by 60 feet, and would have accommodated eleven leads, properly spaced, for work on the hurdle lines.

The piles driven by this combination are seventeen to thirty-one, inclusive.

The times required to move the flat was as follows: 9.4 minutes, 11.4 minutes 8.4 minutes, 34.0 minutes. The first three were simple shifts on the same line; the fourth was a general move from the down-stream (brace) line to the up-stream (drift) line, a distance of about 60 feet across the current and 40 feet up-stream. In the position on the up-stream line three anchors were used (average weight 200 pounds), and when the strain was brought evenly on them they held perfectly.

Two were unable to hold the flat alone. Great trouble was found in raising the anchors after the experiment was over, they had penetrated so deeply under the heavy strain.

The drivers did about two-thirds as much work as usual when thus combined, and this, although all three had to wait till the slowest one had driven its pile.

The result of the experiment seemed to indicate that there was no special difficulty in holding and moving such a flat.

The cost of building such a large hull, stiff enough to support the great weight which would be concentrated on one end, and of constructing such complicated machinery as eleven leads run by a single engine would demand, is so great that before recommending it a further test is deemed needful. With this idea I have designed a three-lead driver to be floated on one of the present hulls.

The machinery remains unchanged, and the only expense is the construction of two new leads, and a general change of position of the machinery, in order to trim the flat.

Plate —* is drawn to a scale of half inch = one foot, and will be found to be sufficiently accurate to be used as a working drawing.

The flat will be available for a common driver if the results do not fulfill all that is anticipated; the extra leads will be available at any time in the repair of other drivers, and the expense of moving the machinery back to its present place is all that is needed to reconvert the multiple into a common driver.

All necessary details can be readily obtained from measurements on the drawing.

Very respectfully, your obedient servant,

FREDERIC V. ABBOT,
First Lieutenant of Engineers.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

* Plate not forwarded.

5455—E 83——81

16.

Record of gauge at Grafton, Ill., for the fiscal year ending June 30, 1883.

[Height of water above plane 200 feet below the Saint Louis City directrix.]

Day.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April	May.	June.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	212.28	201.88	197.50	195.74	198.70	199.12	197.45	199.50	211.45	202.85	205.15	207.90
2	12.95	01.85	97.72	95.68	98.70	99.00	97.12	199.25	11.15	02.50	05.45	07.50
3	13.80	01.80	97.54	95.60	98.65	98.35	97.00	198.00	10.60	02.08	05.75	07.20
4	14.30	01.70	97.55	95.55	98.50	98.00	96.70	198.10	10.20	01.52	06.05	06.83
5	14.50	01.48	97.52	95.48	98.45	97.75	96.40	198.32	09.90	01.00	06.36	06.30
6	14.50	01.52	97.68	95.46	98.30	97.30	96.25	198.55	09.35	01.15	06.50	06.10
7	14.30	01.70	97.75	95.45	98.00	97.00	96.00	198.50	09.40	01.43	06.75	06.00
8	13.98	01.75	97.90	95.40	97.92	96.50	96.00	198.35	09.30	02.50	06.93	06.18
9	13.50	01.60	98.10	95.40	97.80	96.15	95.85	198 22	08.95	03.12	07.10	06.60
10	12.85	01.32	98 24	95.40	97.64	95.00	95.70	198.10	08.50	03.12	07.20	07.12
11	12.15	01.00	98.20	95.50	97.52	94.62	95.50	198.05	07.90	02.93	07.20	07.70
12	11.50	00.65	98.25	95.54	97.45	94.00	98.30	198.00	07.40	02.72	07.18	08.04
13	10.75	00.26	98.00	95.55	97.50	93.85	99.05	198.05	06.90	02.61	07.10	08.40
14	10.00	199.92	97.90	95.75	97.75	93.65	200.25	199.52	06.35	02.40	07.25	08.85
15	09.30	99.70	97.78	96.00	97.65	93.65	00.25	202.00	06.12	02.4 5	07.42	09.35
16	08.70	99.62	97.65	96.15	97.50	93.85	00.58	05.10	05.95	02.50	07.65	10.15
17	08.14	99.55	97.58	96.20	97.60	94.00	01.40	07.70	05.40	02.50	07.82	11.85
18	07.70	99.30	97.35	96.75	97.60	94.00	01.50	08.85	05.35	02.63	08.00	12.00
19	07.25	99.05	97.10	97.30	97.95	94.20	00.55	10.25	05.28	02.75	08.70	13.75
20	06.80	98.80	97.00	97.50	98.05	94.50	199.00	11.00	05.20	02.93	09.10	13.85
21	06.35	98.62	96.92	97.65	98.20	94.50	99.42	11.30	05.15	03.00	09.30	14.27
22	05.00	98.45	96.70	97.75	98.20	94.95	99.00	11.85	05.10	03.30	10.00	14.50
23	04.65	98.35	96.50	97.80	98.40	95.75	98.50	09.72	05.02	03.52	10.00	14.62
24	04.44	98.20	96.40	97.80	98.42	96.25	98.10	12.05	04.94	03.91	10.00	14.65
25	04.20	98.20	96.32	97.92	98.58	96.75	97.00	12.05	04.70	04.05	09.75	14.70
26	03.80	98.20	96.25	97.92	98.75	97.10	98.65	11.98	04.15	04.15	09.40	14.25
27	03.32	98.14	96.08	98.00	98.75	97.35	200.00	11.65	03.70	04.30	09.20	13.80
28	02.90	97.90	95.95	98.22	98.80	97.35	199.70	11.50	03.30	04.43	08.72	13.05
29	02.62	97.72	95.92	98.40	98.92	97.40	99.80	.....	03.00	04.55	08.54	12.45
30	02.45	97.55	95.85	98.50	99.00	97.52	200.00	.....	02.65	04.86	08.30	11.40
31	02.12	97.30	.....	98.65	.....	97.55	00.15	.....	02.14	.....	08.02	.....

Navigation suspended on account of ice, December 7 to December 23, and from January 1 to February 25.

17.

Record of gauge at Gray's Point, Missouri, for the fiscal year ending June 30, 1883.

[Height of water above a plane 200 feet below the Saint Louis City directrix.]

Day.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	115.21	104.91	98.01	95.11	97.81	98.21	96.51	95.11	117.51	106.01	107.51	113.41
2	15.91	04.61	97.91	95.01	98.11	98.11	96.16	94.21	17.11	06.21	07.41	12.66
3	16.61	04.06	97.81	94.86	98.31	97.91	96.01	94.31	16.41	05.91	07.41	12.11
4	17.46	03.91	97.81	94.76	98.41	97.61	95.61	97.21	15.66	05.01	07.51	11.66
5	18.21	04.16	97.91	94.71	98.31	97.51	95.31	96.81	14.66	05.01	07.41	11.21
6	18.51	04.66	97.71	94.61	98.16	97 31	95.11	96.51	13.66	05.44	07.41	10.61
7	18.61	05.11	97.71	94.51	98.01	97.11	94.61	96.51	12.66	05.61	07.31	10.21
8	18.61	05.11	97.56	94.41	97.91	96.66	94.16	96.41	12.21	05.41	07.21	10.61
9	18.41	04.66	97.56	94.41	97.81	95.76	93.76	96.41	11.91	06.11	07.11	11.66
10	18.11	04.11	97.56	94.41	98.01	95.21	93.66	96.01	11.51	06.76	07.11	13.01
11	17.51	03.66	97.71	94.31	97.66	94.41	93.41	97.01	11.16	07.41	07.11	13.21
12	16.46	03.31	97.81	94.41	97.91	93.46	92.66	97.81	10.31	07.61	07.01	13.51
13	15.51	02.76	97.81	94.51	98.41	92.66	92.51	98.51	09.41	07.61	07.01	14.61
14	14.41	02.51	97.81	94.66	98.11	92.16	92.11	100.21	08.66	07.41	07.01	14.66
15	13.36	02.06	97.61	94.76	98.41	92.91	91.66	103.91	08.01	07.31	07.01	15.41
16	12.51	01.66	97.36	95.01	97.91	91.76	91.66	106.51	07.31	06.91	07.21	16.51
17	11.76	01.51	97.21	95.31	98.01	91.11	92.01	111.91	07.11	06.91	07.91	17.41
18	11.31	01.16	97.01	95.41	97.66	90.66	92.31	115.21	06.66	06.31	08.91	18.11
19	11.06	00.91	96.91	95.51	97.16	90.51	92.66	117.66	06.41	06.31	10.21	18.66
20	10.91	00.51	97.11	95.76	97.01	90.66	92.66	118.31	06.11	06.11	11.81	19.41
21	10.66	00.11	96.86	96.41	96.91	91.41	91.76	117.66	05.91	05.66	13.11	19.91
22	10.61	99.76	96.51	97.01	96.91	92.41	91.31	117.01	06.01	07.41	13.51	20.31
23	10.31	99.61	96.41	97.16	96.91	92.76	90.76	117.01	06.11	08.66	13.91	20.51
24	09.66	99.31	96.21	97.16	97.01	93.66	90.76	117.31	06.01	09.51	14.01	21.01
25	08.76	99.11	96.01	97.16	96.81	94.66	91.01	117.66	06.01	09.66	13.41	21.21
26	08.01	98.91	95.76	97.16	96.91	95.61	91.31	118.11	06.01	09.31	13.41	21.51
27	07.31	98.91	95.51	97.16	96.81	96.31	92.11	118.11	05.76	09.01	12.81	21.66
28	06.51	98.66	95.21	97.31	96.81	96.66	93.01	117.66	05.66	08.41	12.51	21.66
29	05.66	98.61	95.51	97.31	97.01	96.66	95.16	.....	05.61	08.01	12.51	21.51
30	05.31	98.51	95.21	97.41	97.11	96.66	95.76	.....	05.41	07.66	13.51	21.11
31	05.11	98.41	.....	97.51	.....	96.61	94.91	.....	05.41	.....	14.01	.....

Navigation suspended on account of ice, January 2 to February 6, and from February 16 to February 20.

18.—*Depth of water upon the bars between Saint Louis and Cairo as reported by pilots.*

[In feet.]

Date.	Stage above standard low water by Saint Louis gauge.	Name of steamer furnishing report.	Arsenal Island.	Horsetail.	Carroll's Island.	Twin Hollows.	Board's Island (head).	Board's Island (foot).	Jim Smith's.	Sulphur Springs.	Foster's Island.	Herculaneum Swashin.	Cornice Island.	Selma.	Forest Home.	Perry's, T. H.	Fort Chartres.	Cambria Hollow.	Turkey Island.	Saint Genevieve Bend.	Kaskaskia Island, Fairy Island.	Saline Creek.	Pratt's Bend.	Mary River.	Liberty Island.	Jones Point.	76 Crossing.	Grand Tower Island.	Crawford's.	Moccasin Springs.	Hamburg, Bainbridge.	Kinney Point.	Devil's Island.	Jacket Pattern.	Goose Island.	Hacker's Bend.	Thompson's.	Greenleaf's.	Abel's, T. H.	Pond Lily.	Eliza Point.	Greenfield's.	Cairo Point.
1882.	*Feet.*																																										
Aug. 1	13.30	Humphreys	22	21	18	10½	12	...	16	9	...	12	10½	16	12	9½	20	...	18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	12.90	....do	21	20	18	9½	10½	...	18	9	...	12	10½	16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	12.90	John B. Maude	...	...	...	8½	9	...	...	10½	...	...	...	...	...	15	13½	...	...	...	...	...	...	...	12	...	...	...	...	...	12	...	10½	...	15	...	9	...	...	15	...	...
3	13.00	Henry Lowrey	...	...	...	8	8½	...	9	18	...	9	...	...	9	12	...	...	...	...	...	...	...	...	9	9	...	...	...	...	...	7½	9	12	12	...	...	...	...	...	...	...
5	13.85	City of Cairo	21	16½	16½	9	12	...	16½	9	...	...	16½	...	...	12	...	...	...	...	...	...	...	...	...	12	...	...	16½	...	8	21	10½	...	10½	...	...	...	...	...	...	...
5	13.85	City of Helena	...	16½	...	9	10½	...	12	...	...	9	...	...	10½	9	...	...	...	...	...	15	...	...	...	12	...	...	...	...	9	...	9	9	12	...	...	...	...	...	...	...
5	13.85	City of Vicksburg	...	15	16½	9	9	...	13½	9	...	...	15	9	...	9	12	...	...	...	...	13½	...	...	15	...	...	...	16½	...	18	10½	...	9½	12	10½	...	10	...	...	...	...	...
6	13.85	Humphreys	22	21	21	9½	12	...	16	12	12	12	...	12	16	10½	18	...	18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	13.80	Ste. Genevieve	...	...	...	8½	9½	...	...	12	...	...	...	13½	...	...	...	...	...	...	...	...	...	...	12	18	...	...	...	10½	...	8½	...	12	12	...	...	13½	...	...	...	...
8	13.45	Anita	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10½	13½	...	...	...	...	...	...	...	...
9	12.90	....do	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13½	15	15	...	13½	...	...	15	...	...
9	12.90	Humphreys	22	21	21	10½	10½	...	15	10½	12	16	10½	18	12	10½	18	...	16	12	12	10½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	12.90	City of Baton Rouge	...	10½	...	7	8	...	...	9	...	...	12	12	...	12	15	...	...	...	...	13½	...	...	10½	13½	...	...	...	...	...	...	9	10½	...	...	12	...	...	...	...	...
10	12.45	Humphreys	21	20	20	10½	10½	...	12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	11.50	....do	21	20	20	10½	10½	...	16	9	12	12	10½	20	12	10½	18	...	15	10½	10½	10½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	11.50	City of Greenville	...	10½	...	8	9	...	...	...	...	...	12	...	12	9	12	...	...	...	...	9½	...	...	9	12	...	...	12	9	...	8½	...	...	12	12	...	12	...	...	...	...
12	11.50	City of Helena	...	...	...	8	8	...	...	10½	...	...	9	...	...	7	15	...	15	...	...	13½	...	...	13½	15	...	...	13½	12	...	10½	...	8	12	12	...	10½	21	...	21	...	...
13	11.20	City of Alton	...	12	16½	9	9	...	...	8½	...	...	...	...	...	10½	12	...	...	...	...	9½	...	...	...	9½	...	...	12	9	15	9	13½	9	10½	12	...	...	...	18	13½	...	...
14	10.70	Ste. Genevieve	...	...	...	8	8	...	...	8	...	...	...	12	9	...	...	...	...	...	...	...	...	...	10½	10½	...	...	...	...	...	9	...	...	...	...	...	12	...	...	...	...
15	10.30	Humphreys	20	18	16	9½	9½	...	12	9	...	12	10½	8	9	9½	12	...	12	10½	12	10½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	9.95	....do	19	18	16	9	9	...	12	9	10½	12	10½	...	9	10½	12	...	10½	10½	12	9½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	9.95	City of Cairo	...	10½	...	9	9	...	13½	9	...	...	...	...	...	...	12	...	...	...	10½	...	...	12	...	...	...	...	12	...	...	...	9	10½	9½	...	15	...	...	...	...	...
18	9.60	City of Helena	...	...	...	6	8	...	...	8	...	...	8	...	...	8	12	...	10½	...	...	10½	...	10½	9	...	...	...	10½	8	...	...	7	10½	12	13½	15	15	...	...	...	...
19	9.20	City of Vicksburg	...	12	...	9	9	...	13½	7½	...	...	...	...	...	8	...	...	...	...	...	10½	...	10½	8	...	...	...	10½	12	8	...	...	...	10½	...	12	...	...	...	...	...
19	9.20	Humphreys	19	17	12	8	9	...	10½	8	9½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20	8.70	A. P. Silver	...	...	...	8½	6½	...	12	8	...	...	9	...	...	6½	10½	...	...	12	9	...	...	8½	9	...	...	...	9	9	9	...	...	8	12	10½	...	9½	...	...	...	...	...
21	8.45	Ste. Genevieve	2	...	...	8	7½	...	...	8	...	...	9	...	...	...	...	...	...	...	...	...	...	...	9	9	...	...	...	7	...	7½	...	7½	...	8	...	...	...	...	...	...	...
22	8.15	City of Providence	...	9	...	6	6	...	...	7	12	9	...	...	...	...	12	...	...	10½	...	...	...	10½	8½	...	...	...	9	7	10½	7	...	...	10½	...	12	...	...	...	...	...

22	8.15	Humphreys	18	16	15	9	9	12	8	10½	10½	10½		8½	9	12		10½	10½	11	9½																					
23	7.90	Humphreys	18	16	15	7½	8	12	8																																	
23	7.90	John B. Maude					6		7						6	10½								7				9	9		6½		7	9	9		12					
24	7.80	Commonwealth				7	7		7½			9			6									8				8½	8½		6½		6½									
24	7.80	City of New Orleans				9	7		7½		10½	8½			8½								9	7				9	8		7½		9½		8½		12	12				
25	7.60	Humphreys		16	15	8	8	10½	8		12	12	9	8	9																											
26	7.55	Arkansas City				7	6		7½		12	8½	7		8½	9			12		9		9	6				10½		9	7		7		10½							
28	7.05	Ste. Genevieve		10½		7	6		5½			9	6			8½				10½				6							6											
29	6.90	Humphreys	17½	14½	15	8	7½	10½	7½	9	9	10½	8	6	9																											
30	6.70	John B. Maude	12	9		8	7		7			9	8		7	9								7				8		9	7		7	9	9		12			12		
31	6.60	Baton Rouge	10½	8	9	9	6½	12	7	10½	12	8	7		8	9		7	9		6		10½					6½	8	9	7		7½	9	8½		10½	9		9		
31	6.60	City of Cairo		10½	12	9			6		12	7		8	8	8					9			5½				8	8		7		5½	7	8			10½				
31	6.60	Humphreys	17	14	14	8	8	12	8	9	10½	10½	9	8																												
Sept. 2	6.55	....do	17	14	14	8	8	12	8	10½	10½	9½	9	8		12		9	9	12	9																					
2	6.55	City of Vicksburg		9	10½	8	6½	10½		13½		10½	12	8	8	8			9		8		8	6				8	7	8	6			12	9	12	12	12	10½			
3	6.65	City of Alton			9	7½	6½	12	6½			7½	8			12		7½	9	9			8½	6		9		6½	7½	10½	7½		7½	9			8			12		
4	6.40	Ste. Genevieve		9		7	6		5½			9	7		6½	7½				8½				7	6½			6½	8½		6		6									
4	6.40	Anita																							6½			8	9	9	7											
5	6.35	Humphreys	16	13	14	8	6½	10½	6½	9	9	9½	7	8	7																											
5	6.35	Anita								8		9	7		7	9			12	8			9																			
6	6.35	....do		9		6	7		7	8		8	7		7	8			12	8																						
6	6.35	City of Providence		8	12	8	8	15	8	13½	12	7½	10	8	7½			8½	10½		8		9	6				7	9	8	6½		7	8	9	12	12					
6	6.35	John B. Maude	10½	8½	13½	7½	5		7			6		6		7							9	7				9	7½	8	7		8	9	10½					10½		
6	6.35	W. P. Halliday				6	6½		7					6½		8					9			5½				8	8	10½	6		7	10½	8		10½	10½		12		
7	6.30	Humphreys	16	12	14	8½	7	10½	7																																	
7	6.30	Anita																					8½	5½				8	9	9	6											
7	6.30	Commonwealth		8	12	8	6½	12	6			8	8		8			8½			9			6				7½	6	9	6			8			12			12		
8	6.30	Humphreys	16	10½	14	9	6½	12	6½	9																																
9	6.50	Arkansas City		9	12	9	7½		7	9			7		8	12		8½	10½		8		10½	7	7			8		12			7		9		12					
9	6.50	Annie P. Silver	10½	8½	10½	8½	6½	12	7½			5½	9	7	6	12	7		12		8½		9	7		9		8½	7½	6½	7		8		7½	9½	10½	6½				
11	6.60	Ste. Genevieve		9	9	8	6½		8		9	8	8		7½					9			9	9	10½			8½	9	9	6½		6									
12	6.50	Humphreys	15½	10½	14	9½	8½	12	9½	9	8½		7	9	7½	10½	7	9	8½	12	9½																					
13	6.45	....do	15½	10½	14	9½	8½	10½																																		
13	6.45	John B. Maude		8		10	7		7			6½	7		6			8			6		8	5½					8	8			5½									
14	6.25	Humphreys	15	10	13	8½	8½	10½																																		
15	6.05	....do		10	13	8½	9	10																																		
15	6.05	Anita																					8½	6½				8½		9½	6½											
16	5.95	....do																					8	6½						9	6											
16	5.95	City of New Orleans		8	9	8½	7½	12	7½			8	6½		6	7½			10½		8		9	6½		8½		7	8	9	7		7	8	7½		12	9				
17	5.75	John A. Scudder			13½	8	8	13½	8½			8½	7½	6			8½		10½					6	8½			6	7	9	6½		6½		9		13½	13½				
17	5.75	Humphreys	14	9½	13	9	9	9½																																		
18	5.55	Ste. Genevieve				7	7		7			7	6		6		7			6			8	5½	9			6			6		6		9							
19	5.45	Humphreys	13½	9½	13	9½	9½	9½																																		
19	5.45	Anita																					8	6				8	8	9½	6											
20	5.25	....do																					8					8	8	9	6											
21	5.00	Humphreys	13½	9½	18	9½	9½	9	6½	8	9	8	7	6	6½	9½	6½	8	7½	12	8																					
23	4.75	....do	12	9	12	9	9	9																																		
25	4.40	....do	12	9½	10½	9½	9½	9																																		
27	3.90	....do	10½	8½	9½	9½	9	9																																		
29	3.75	....do	9½	8½	9½	9½	8½	9½																																		
30	3.60	City of Vicksburg		6½	8½	9	7	10½	6	13½	8	5½		5½	4½		7		10½		7		6½	6				5½	7	7	6		6				8½	7		8½		13½
30	3.60	Humphreys	9½	8½	9½	9½	9	9½	5½																																	

18.—*Depth of water upon the bars between Saint Louis and Cairo as reported by pilots*—Continued.

[In feet.]

Date.	Stage above standard low water by Saint Louis gauge.	Name of steamer furnishing report.	Arsenal Island.	Horsetail.	Carroll's Island.	Twin Hollows.	Beard's Island (head).	Beard's Island (foot).	Jim Smith's.	Sulphur Springs.	Foster's Island.	Herculaneum Swashin.	Cornice Island.	Selma.	Forest Home.	Perry's T. H.	Fort Chartres.	Cambria Hollow.	Turkey Island.	Saint Genevieve Bend.	Kaskaskia Island, Fairy Island.	Saline Creek.	Pratt's Bend.	Mary River.	Liberty Island.	Jones Point.	76 Crossing.	Grand Tower Island.	Crawford's.	Moccasin Springs.	Hamburg, Bainbridge.	Kinney Point.	Devil's Island.	Jacket Pattern.	Goose Island.	Hacker's Bend.	Thompson's.	Greenleaf's.	Abel's T. H.	Pond Lily.	Eliza Point.	Greenfield's.	Cairo Point.
1882.	*Feet.*																																									
Oct. 2	3.50	Ste. Genevieve	...	6	9	7½	8	...	...	5	...	6½	6	7	6	4½	6	...	...	8	6	...	7	6	5	7	...	5½	5	...	...	8	...	...	7½	8	9	...	6½	...	...
3	3.40	City of Providence	9	5½	10½	8½	8	...	...	6	...	9	5½	6	7	7	7	...	...	8	...	7	6	6	6	...	7	...	6	6	6	4½	...	8	...	...	...	...	...	...	...	...
3	3.40	Humphreys	9½	8½	9	9½	9	9	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	3.20	Anita	...	6	9	8	7½	7	5	7	...	...	5	7	5	5½	7	6	...	8	7	7½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	3.20	Wyoming	...	6	9	10½	8	9	...	4½	...	8½	5½	...	...	5	9	6	...	9	...	6	6	6	5½	6	7	...	5½	4½	8	5½	...	5	7½	...	9	7	8	...	8	10½	...
6	3.20	Anita	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	6	...	...	...	5	6	8	5	...	...	...	...	...	...	...	...	...	...
7	3.20	Humphreys	9½	8½	9½	9½	8½	9	9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	3.20	Arkansas City	12	9	9	7	8½	9	...	5½	...	...	5½	7	5½	6½	...	...	9	10½	6	...	6	5	5	...	8	6	5½	5	8	5	...	6	6	...	9	9½	...	9½	10½	...	...
7	3.20	Commonwealth	...	...	...	...	...	...	...	...	...	...	...	...	...	6½	...	...	...	...	...	...	...	...	...	...	...	6	6	...	...	...	...	...	...	...	...	...	...	...	...	...
8	3.10	John A. Scudder	7	6	...	...	8	...	...	...	...	...	4½	...	...	...	...	...	...	...	...	6	...	6	6	...	...	...	6	6	...	...	5	...	...	...	...	...	...	...	...	...
9	3.10	Ste. Genevieve	...	6	8½	7	7	...	...	5½	...	...	6	...	5	5½	7	...	...	...	7	6	6	5½	4½	6	...	...	5½	6	...	...	5½	...	...	...	...	...	...	...	...	...
10	3.20	Humphreys	9½	8½	9	9½	9	9½	8½	5½	10½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	3.20	....do	9½	8½	9½	9	9	9½	8½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	3.20	D. R. Powell	9	6	9	7	8	...	...	5½	10½	7	5½	9	6	6	9	7	9	9	...	7	6½	6	5½	...	6½	...	6	5½	8	5	...	6½	6½	...	...	9	...	9	9	...	...
12	3.20	City of Cairo	...	6	9	...	9	...	...	5½	...	9	6	6½	5½	7	5	...	...	...	5½	...	...	5½	6	...	6½	...	6	...	7½	5½	...	...	7½	...	...	...	...	...	...	...
13	3.50	Humphreys	9½	8½	9½	9	9	9½	9	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	3.50	City of Helena	9	6	9	9	9	...	...	6	...	...	5½	...	6	6	...	9	7	9	...	7	6	6	6	6	...	...	6	7	9	6	...	6	...	...	...	...	...	...	...	...
13	3.50	City of Vicksburg	...	6	9	9	7½	...	...	6½	...	...	...	...	6	7	...	9	...	...	...	7	7	7	6	...	...	...	5½	6½	9	5	...	6	...	...	9	...	8½	15	...	...	...
14	3.75	Humphreys	9½	8½	9	9½	9	9½	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	3.95	Chas. P. Chouteau	8	6	9	7	5½	...	...	5½	...	...	5½	6	...	6	...	...	...	...	...	...	6	5½	...	...	...	...	5½	6½	...	6	...	6½	9	...	...	9½	8	...	10½	...	9
16	4.05	Humphreys	10½	9	9½	9	9½	9½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	4.20	....do	10½	9	9½	9½	9½	9½	10½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	4.20	Anita	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8	6	...	9	6	...	...	...	...	...	...	...	...	...	...	...
18	4.50	City of Providence	...	7	9	...	...	...	6½	...	...	7	7	6½	...	12	...	...	9	...	8	7	7	6	6	8	5½	6½	7	11½	6	...	7	...	...	8½	10½	9	...	12	8½	...
19	5.05	Humphreys	12	9½	12	10½	10½	10½	10½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
19	5.05	Belle of Shreveport	...	7½	10½	...	9	...	...	7	...	...	6½	7	...	8	...	...	...	...	...	...	...	8½	7	...	...	...	8½	...	...	7	...	7	...	...	...	...	...	...	...	...	...
21	6.10	Humphreys	12	9½	12	10½	10½	10½	12	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	6.10	Annie P. Silver	...	8	12	10½	9	...	...	7	...	...	8	9	7	9	...	10½	...	10½	...	8½	8	8½	8	8	9	8	8	...	8½	7½	...	8½	9½	...	...	10½	...	...	13½	...	...

	22	6.10	Sam. Roberts		8	13½	9	10½			7				9	8	8½			10½		8		8	9	8	8½			8½	7	8½	7½											
	23	6.06	Humphreys	12	9½	12	10½	10½	10½	12																																		
	23	6.06	Ste. Genevieve				9	12			6			6½		7	8	10½				9	8			7							6		7									
	24	6.07	Humphreys	12	9½	12	10½	10½	10½	12																																		
	25	6.04	do	12	9½	12	10½	10½	10½	12																																		
	26	6.10	do	12	9½	12	10½	10½	10½	12																																		
	27	6.06	do	12	10	12	10½	10½	12	12																																		
	28	6.12	City of Baton Rouge	12	7½	12	9	12			7½			7	6			12	12		9		8	7	9	8			8	8½	8	9	7½		8½	9					10½	13½	10½	
	28	6.12	Humphreys	14	10½	13	10½	10½	12	12	9																																	
	31	6.80	J. F. Maude		7						8			8		8½	8	10½						10½	8	8		9		8	9	12	7											
Nov.	1	7.15	Humphreys	14	10½	13	10½	11	12	12	9																												12		12	12		
	2	7.15	Anita		8½	13½	12	13½	12	12	7	9½	8½	7	9	8	9																											
	2	7.15	Humphreys	14	10½	13	11	12	13	13																																		
	3	7.10	do	14	11	13	11	12	13	13																																		
	3	7.10	Commonwealth								7		7	8		8	8									7				8½	9	9	7		8½				9					
	4	6.90	Arkansas City		9	12	12				8		10½	7½	12	9	10½		15						10½	9		15		7½			9		10½				13½					
	4	6.90	Humphreys	14	10½	13	11	12	13	12	9																																	
	4	6.90	Anita		9	13½	13½	13½	13½	12	8	9	9	8	9	9	9	9¼	10½		10½	9½	9½	9	10½	8	9																	
	6	6.57	Humphreys	14	10½	13	11	12	12	12	8½																																	
	9	5.95	do	14	10½	13	10½	12	12	12	8																																	
	9	5.95	City of Cairo		10½						6			8	9	9					12		10½	9	10½	8	8	12		9														
	12	5.90	David R. Powell		8½						6½			7		8½	7½									8½					9		8		8½					9				
	13	6.12	Humphreys	14	10½	13	10½	12	12	12	8																																	
	15	6.90	Anita		9	15	12	12		13½	9		12	9½	12	9½	9½	10½	10½		12	9½	10½	9																				
	15	6.90	Humphreys	14	10½	13	10½	12	12	12	8½																																	
	15	6.90	Annie P. Silver								8			8½		9	9		12						9	7½	9	13½		9	10½		8		8½				10½					
	17	6.42	Humphreys	14	10½	12	11	12	12	12	8																																	
	19	6.42	Halliday	12	7½	12	10½	12			8				9	7	7½	12		10½	10½	8½		8½	10½	9				7½	8	9	8		8				9	8			10½	
	20	6.50	Humphreys	14	10½	12	11	12	12	12	8																																	
	20	6.50	J. B. Maude		9						6															9½		9		9			8		9					9				12
	22	6.68	Humphreys	14	10½	12	11	12	12	12	8																																	
	22	6.68	City of Baton Rouge		8	13½	13½	15			8	10½		8		10½	9		15		12		9	9	9	8		12	9	8½	9	10½	8		9				12				10½	
	24	6.60	Humphreys	14	10½	12	10½	12	12	12	8																																	
	24	6.60	City of Cairo		10½	12					8																			9					8									
	27	6.70	J. B. Maude		9						6½			9		9	8	12					8		8	9			8	9			7		9					8				
	28	6.77	Humphreys	14	10½	12	10½	12	11	11	8																																	
	29	6.90	do	14	10½	12	10½	12	12	12																																		
	30	6.90	do	14	10	12	10½	12	10½	12	7½																																	
Dec.	1	6.70	do	14	10	11	10½	12	10½	12	7½																																	
	2	6.50	Arkansas City		8		12	9			6			9		8	8		15				8		8	8				8½	9	9	7½		8½									
	3	6.12	City of Greenville		9		12	12			7½			7	8	7½	8	10½			13½	8½		9	9½	8		12	9	8	9	13½	7½		9½							15		
	4	5.75	J. B. Maude		8						6			8			7	10½					9	9	9	8		12	8	8½	8		7½		9				9	9	15		9	
	23	1.90	Cinton	12	6	13	13	13½	12			12	9	6½	6	6½	7½	12			8		9½	7	6	6	8	9												9½				
	24	2.95	A. P. Silver	10½	8		7½				7½	8		7	6	6	6		8		13½		8	12	6½	6		6	7	6	8	7½	7½		6	9	8	9½	8		12	10½		
	26	4.30	D. R. Powell	5½	5½	9	5½				4½	8½	5½	4½		4½	7	8½		6	7½				6½	5		8	5½	7	9	7½	5½		6½		8	10½	10½	12				10½
	26	4.30	Commonwealth		9			10½			8	12		9		9	10½		10½		9½		9	7	8	7	8		9	7	9	9	6½		7½				13½	12				
	27	4.50	Ste. Genevieve		7		8½	13			6½		7	7		7	7				10½		9	7	5	6	7	9	7	6	8½		8½		8½	9	12	9		10½				
	28	4.50	City of Greenville		8	16½	12	15	15	16½	9	15	12	9	9	10½	13½	16½			8		8	10½		7½	9		7	8	8½	9			9	10½	10½	13½	16½	12	16½	16½		

T 2.

IMPROVEMENT OF THE HARBOR AND MISSISSIPPI RIVER AT ALTON, ILLINOIS.

Operations at this locality were carried on under an allotment made by Congress from the general appropriation for improving the Mississippi between the Illinois and Ohio rivers. Their history is given in the report upon that work. The favorable season of last autumn enabled the work to be done at a less cost than that previously estimated. The dike advanced so far towards completion and its action upon the shoal in front of Alton landing has been so favorable that it is quite probable that the desired result will be attained without fully completing the dike as originally designed. Considerable settling, however, is to be expected, and in order to preserve the present efficiency of the dike a sum of money sufficient to keep it in repair should be available. An appropriation of $5,000 is accordingly recommended.

Money statement.

Amount (estimated) required for completion of existing project.....	$5,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1885.	5,000 00

T 3.

IMPROVEMENT OF MISSISSIPPI RIVER OPPOSITE THE CITY OF SAINT LOUIS, MISSOURI.

The river and harbor act of August 2, 1882, contained the following proviso, viz:

> That the unexpended sums heretofore appropriated for an ice harbor at Saint Louis, Mo., be, and the same are hereby, transferred and appropriated, to be expended under the direction of the Secretary of War, for the improvement of the channel of the Mississippi River opposite the city of Saint Louis, Mo., by repairing and raising the present low dam across the channel east of Arsenal Island, known as Cahokia Chute, and by the construction of such other works in or near said Cahokia Chute as may be deemed advisable to accomplish the same purpose.

The sums above described amounted to $60,000.

The locality is shown upon Plate I. The submergible dam across Cahokia Chute, constructed in 1878 and 1879, was originally built to a height of about 5 feet above standard low water, but it had afterwards settled about 3 feet, leaving its crest about 2 feet above standard low water. It had accomplished the object that was expected of it, viz: Directing the channel to the other chute and removing the shoals at the head and at the foot of Arsenal Island. It had caused heavy deposits in Cahokia Chute, large areas of which had reached a height much greater than the dam, and were dry at medium stages. At the higher stages, however, a considerable body of water still passed through this chute, and modified the direction of the channel below, causing certain complications at Horsetail which it was desirable to remove. At such times also there was apt to be a slight erosion of the upper portions of the Illinois bank below the dam. To provide for the future business interests of the locality it will eventually be necessary to entirely re-

claim Cahokia Chute in order to afford free access to the navigable water west of Arsenal Island, increasing at the same time the amount of land available for occupation. One object, then, of the works to be constructed was to fill up Cahokia Chute with deposits of silt.

An important feature of the improvement of this locality is the protection of the west side of Arsenal Island. This work had been begun under the general appropriation for the improvement of the Mississippi River, between the Illinois and Ohio rivers, and was in August last well advanced towards completion. There remained, however, to deposit riprap upon the bank above low water for a length of about 3,375 feet. It was decided to complete this work under the appropriation now under consideration.

One means of hastening the process of filling up the chute was to raise the dam by methods similar to those employed in its original construction, viz, by building it up with layers of brush and stone. Both on account of the wording of the law and on account of the slow action of hurdles located on the east side of the Mississippi so near the Missouri, this method would have been adopted had it been found practicable. An examination made in September showed, however, that portions of the dam were buried in sand to a depth in some cases of 12 feet. It showed also that it would not be possible to enter the chute with vessels during the low-water season which was to follow, and that all operations must be postponed until spring. The latter season being most favorable to the prompt action of hurdles, it was decided to attain the desired result by means of them.

Two hurdles were laid out, one just above the dam and parallel to it and one about midway between the dam and the up-stream end of the chute (see Plate I). Their construction was begun in March, and by the end of the year they were nearly completed. They have caused heavy shoaling, the thickness of the deposit averaging 7 feet over the entire area of the chute above the dam, with a maximum fill in some places of over 18 feet. The amount of solid matter secured is estimated at about 3,000,000 cubic yards.

The work was under the immediate direction of Mr. C. D. Lamb, resident engineer, whose report is appended, marked 19, and under the general supervision of Mr. D. M. Currie, superintending engineer. For details see Appendixes 1 and 19.

The cash expenditures were $33,903.94. The expenditures including use of equipment were $47,067.95, of which $40,873.88 was employed upon the hurdles and $6,194.07 upon the bank protection.

It is thought that the funds now available will be sufficient to accomplish what may be required during the coming year.

No additional appropriation is recommended at this time.

Money statement.

July 1, 1882, amount available		$60,000 00
July 1, 1883, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1882	$32,900 54	
July 1, 1883, outstanding liabilities	1,003 40	
		33,903 94
July 1, 1883, amount available		26,096 06
Amount (estimated) required for completion of existing project		26,096 06

19.

REPORT OF MR. C. D. LAMB, ASSISTANT ENGINEER.

SAINT LOUIS, MO., *July* 6, 1883.

MAJOR: I have the honor to submit the following report of operations at Cahokia Chute for the fiscal year ending June 30, 1883.

The object of this work is to improve the Mississippi River opposite the city of Saint Louis by shutting off the water at medium stages from the channel east of Arsenal Island, known as Cahokia Chute. Previous to 1878 this chute was regarded as the main channel of the river, the passage on the west side of the island being impeded by a bar of nearly uniform height extending from the island to the Missouri shore. This bar was scoured out soon after the building of the low-water dam across Cahokia Chute in 1878 and 1879, which, raised to a height of 5 feet above standard low water, caused a deposit across the head of the chute, practically closing it during low water. In order to effect the same result at higher stages, the construction of hurdles was begun in accordance with your instructions dated March 10, 1883. An examination having been made, it was found that the east bank of the island had been washed away above the dam to a maximum width of 300 feet, while the towhead opposite had been advanced about 600 feet since 1879, and that the crest of the dam had sunk to a height of 2 feet above low water near the island and to about 7 feet lower near the Illinois shore, where the bottom was found to consist of very soft mud overlaid with a deposit of sand varying in thickness from 3 feet to 20 feet. A bar opposite the head of the island divided the chute into two channels; the larger one passed down near the towhead on the Illinois shore, the other flowed down next the island until after passing the dam, when it joined the main channel near the Illinois shore.

Hurdle line No. 1 was located 80 feet above and parallel to the dam, and its construction begun March 17. Work upon it was pushed forward as rapidly as possible, and the line was completed on the 7th of April, but during the sudden rise of April 23 a section of the line 50 feet long, just above the breach made in the dam during its construction, 400 feet from the Illinois shore, was carried away, the bottom at this point being too soft to withstand any considerable pressure, although the piles were driven to a depth of over 20 feet. Contrary to expectation, this breach did not increase in size and was soon repaired, with the exception of the wattling, which was left till the line above should be completed. Repairs were also made upon the island end of the line which was damaged about the same time. These repairs were completed May 11. Meanwhile the construction of line No. 2, begun April 2, had been nearly completed, when work upon it was interrupted May 17 by the high stage of river which completely submerged the piles. At this time 1,300 feet of the line had been completed, and the remaining 1,200 feet was finished with the exception of the wattling.

The river subsided early in June, and work was resumed on the 5th, but another rise again caused its suspension on the 8th; the only work done during the remainder of the fiscal year being the loading on barges of piles delivered at the works in rafts.

The accompanying tracing shows the condition of the work at the end of the fiscal year. The soundings in black were taken July 2. They indicate a large fill during the season, especially at the head of the chute, where the deposit is in places over 18 feet. The average fill over the entire area between the head of the chute and hurdle line No. 1 is about 7 feet, which would indicate a total deposit of 3,000,000 cubic yards.

The method of construction is materially the same as that used on primary hurdles at other places.

The piles in the hurdle row of line No. 1 were driven 6 feet apart, and protected from drift by a line of piles 20 feet above, driven 12 feet apart. Every alternate pile in the hurdle row was stiffened by a brace-drift bolted to its top and extending to the bottom of the river 24 feet below, where it was fastened to another pile by a clevis. To place this brace in position the clevis is first fastened to the heel of the stick and then slipped over the top of the pile and dropped into position by a pile-driver or derrick. The drift-row and the hurdle-row were stiffened by longitudinal stringers fastened to their tops by screw-bolts, and the whole line was further strengthened by cross-stringers at right angles to the line, and bolted to a pile or stringer in each of the three rows. The bottom between the brace and hurdle rows was protected from scour by a foot-mat 37 feet wide, extending from the brace-piles to a distance of 12 feet above the hurdle row. This mat was built of two layers of brush, crossing each other at right angles, thick enough to hold the stone used in sinking, and was supported during construction by grillage-poles lashed to the piles. The wattling was carried to a stage of 20 feet above low water. Soon after it was begun it was found that the depths were increasing between the drift and hurdle rows. Consequently a section of foot-mat was built and sunk to protect the space between these rows.

The method of construction of line No. 2 was the same as that of No. 1, except that the foot-mat was built and sunk in sections 40 feet wide, and the drift-row was braced

at each intersection of the longitudinal stringers, the braces being attached to the piles on the hurdle-row, and the use of the top stringers was regarded as unnecessary.

The following table shows the amount of work done on each line during the fiscal year:

Line.	Piles.	Braces.	Stringers.	Foundation mattress constructed.	Wattling constructed.
Hurdle line, No. 1	676	172	193	112,200	23,400
Hurdle line, No. 2	753	209	85	100,000	14,500
Total	1,429	381	278	212,200	37,900

No injury to either line of hurdles can be detected at this stage of river. The well-defined break seen over their whole length shows them to be unbroken, while the fill at the head of the chute has been so great that the pressure upon them is very much less than during the rise of the latter part of May.

Very respectfully, your obedient servant,

C. D. LAMB,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

T 4.

IMPROVEMENT OF THE MISSISSIPPI RIVER AT OR NEAR CAPE GIRARDEAU, MISSOURI, AND MINTON POINT, ILLINOIS.

A full description of the plan of these works was given in my last annual report. At the date of that report the object of the works had been attained, the shoal in front of the Cape Girardeau Landing having been removed. A hurdle to perpetuate these results was in process of construction opposite the town, and a further appropriation was desired to protect portions of the old bank and of the new deposits.

During the autumn season the hurdle opposite Cape Girardeau was completed to a total length of 3,100 feet, after which all operations were suspended and the public property removed to Saint Louis. This hurdle has since suffered some damage from ice. To repair it and to protect the banks in the vicinity, both old and new, the appropriation asked for last year is again recommended.

The good results previously obtained have been maintained throughout the year, the main steamboat channel flowing without obstruction from one end of the landing to the other.

The work was under the immediate direction of Mr. J. A. Worthen, whose report is hereto appended, marked 20.

Money statement.

Amount (estimated) required for completion of existing project	$41,820 04
Amount that can be profitably expended in fiscal year ending June 30, 1885.	41,820 04

20.

REPORT OF MR. J. A. WORTHEN, ASSISTANT ENGINEER.

SAINT LOUIS, MO., *January* 9, 1883.

MAJOR: I have the honor to submit the following report of operations for improving the Mississippi River near Cape Girardeau, Missouri, and Minton Point, Illinois, during the half year ending December 31, 1882:

CAPE GIRARDEAU.

Work upon the primary hurdle, which had been suspended May 30 on account of high water, was resumed August 1, and extended over a period of eighty-one days.

During the high-water season no changes of importance had taken place in the position of channels or the general behavior of the river.

When the waters had subsided and active operations were resumed it was found that 120 feet of the outer end of the hurdle had been destroyed and a breech 50 feet in length had been made about 300 feet from the shore. Also other slight injuries to the hurdle had resulted from the heavy masses of floating drift-wood. The damage was at once repaired and the work of construction carried toward completion as rapidly as possible.

The river still being above a medium stage, and the decline very gradual, work advanced for a time in from 20 to 24 feet of water and a rapid current. When the hurdle had crossed the channel the construction was less difficult, and work advanced without further annoyance save from sickness and scarcity of labor.

The same forms of construction described in my annual report for the last fiscal year were used. For a distance of 1,550 feet from the shore the hurdle was a combination of the curtain and fixed hurdle, the curtains being placed in depths of water greater than 10 feet and brought to the surface. From the surface of the water to a 20-foot stage of the river the hurdle is of the fixed type, as is also the remaining half of the hurdle beyond this point.

The mattress is of the same form throughout. That portion 2,000 feet in length across the channel in deep water and strong current is composed of three courses of brush, the remainder of two courses, built in sections 130 feet in length by 50 feet in width.

PILE-DRIVING.

In the main the piles have been driven butts down, by means of jet and hammer combined, the exception being that of repairing destroyed portions of the hurdle where the piles were driven through the footing mattress, in which case they were driven tops down, the hammer alone being used.

Careful observations have been taken of this work to ascertain the comparative utility of hard and soft wood piles.

For a time it was maintained by the foremen of pile-drivers, first, that hard-wood piles could be driven deeper than soft-wood; second, that a greater number of piles could be driven in a given time; and third, that they were much more stable when driven. The work of the season, however, has proven that the first two assertions were products of delusion.

The stability of hard-wood piles is acceded. Their superior strength renders them adaptable to construction where excessive strains are to be borne, when their use may be adopted, even at a much greater first cost.

Below is shown the work of pile-drivers for the half year:

Working time	hours..	571
Number of piles driven		603
Average depth driven	feet..	11.78
Average depth of water	do...	16.00
Number of piles driven per hour		1.06
Number of feet driven per hour	feet..	12.44

The work of construction for the half year is as follows:
Hurdle constructed (including repairs), 2,670 linear feet, 46,400 square feet.
Footing mattress, 2,550 linear feet, 127,500 square feet.

In which were expended—

Brush	cords..	1,522.35
Stone	cubic yards..	1,145.15
Piles		929
Bolts		454
Iron	pounds..	3,826
Nails	do....	200
Rope	do....	2,162
Spikes	do....	345
Wire	do....	4,600
Lumber	feet..	575

With this work the primary hurdle was completed October 20, its total length being 3,100 feet.

MINTON POINT.

No work done and none needed. The works remain substantially in the same condition as at the close of the fiscal year last preceding.

CONCLUSION.

Upon the completion of the primary hurdle opposite Cape Girardeau improvements in this locality were abandoned, they having amply performed their proposed work in securing a good harbor at Cape Girardeau and a 15-foot channel at a 9.5-foot stage of water, the entire stretch of river over 4 miles in length, from the head of the works above Minton Point to and past the city of Cape Girardeau.

Accompanying this report is a map showing the extent of the works in good order and the condition of the river at the close of operations.

* * * * * * *

Very respectfully, your obedient servant,

J. A. WORTHEN,
Resident Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

T 5.

IMPROVEMENT OF OSAGE RIVER IN KANSAS AND MISSOURI.

Work during the year consisted mainly in removing snags from the channel and overhanging trees from the bank. At Moore's Flats the shore was protected for a length of about 250 feet, and some small repairs were made to the training walls at Dixon's and Round Bottom shoals.

At the beginning of the year a force was engaged at this work, and so continued until August 3, when it was disbanded. Up to that time two hundred and twenty-eight snags and twenty-three overhanging trees had been removed since July 1 between Big Gravois and the mouth of the Osage, a distance of 82 miles. The river had thus been well cleared of these obstructions for the entire length of about 176 miles below Grand River. Nothing had been done between Grand River and Osceola, the head of navigation, a distance of about 54 miles; but on account of low water it was not possible to reach that part of the river with a steamboat during the summer and autumn. The work was resumed in April, and was carried on at first over the part between Osceola and Grand River, in which one hundred and thirty-eight snags and five hundred and forty-nine trees were removed. It was then continued to the mouth of the Osage, going over the same ground that had been covered before. In this part eighty-five snags and two hundred and eleven trees were removed.

The work was under the immediate direction of Overseer Kimbrough Winston, whose report is hereto appended, marked 21. Attention is invited to this report for details of the work, and for a statement of the commerce of the Osage River for the fiscal year.

The gauges at Tuscumbia and Warsaw were read daily. Their records are hereto appended, marked 22 and 23 respectively.

The expenditures were $9,873.43, leaving an available balance of former appropriations of $1,660.65. Most of this will be consumed in caring for the public property and in keeping the gauges. A new supply of snags and overhanging trees is to be expected in the future, but how rapidly they will accumulate is a matter of conjecture.

It is thought that an appropriation of $5,000 will be sufficient to accomplish all that may be required during the year ending June 30, 1885.

Improvement of Mississippi between Illinois and Ohio Rivers. Annual Report of Major O. H. ERNST, Corps of Engineers. 1883.

PLATE I.

CAHOKIA. CHUTE
AND
ARSENAL ISLAND PROTECTION.

Map showing location of works June 30th 1883.

Scale of Feet.

Bars are shown as they appear at stage 11' above standard low water.

Protection placed during year shown thus ▬▬

" previously placed . . ▬▬

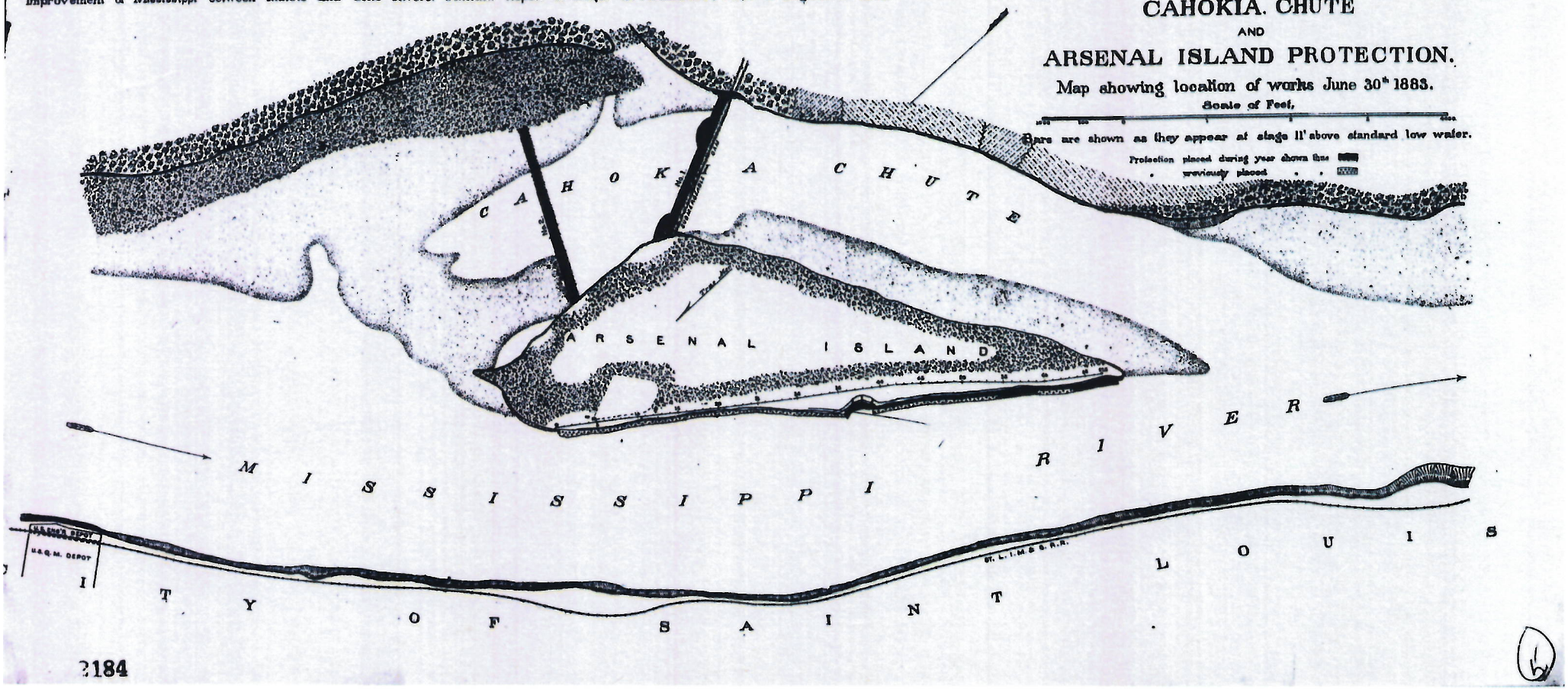

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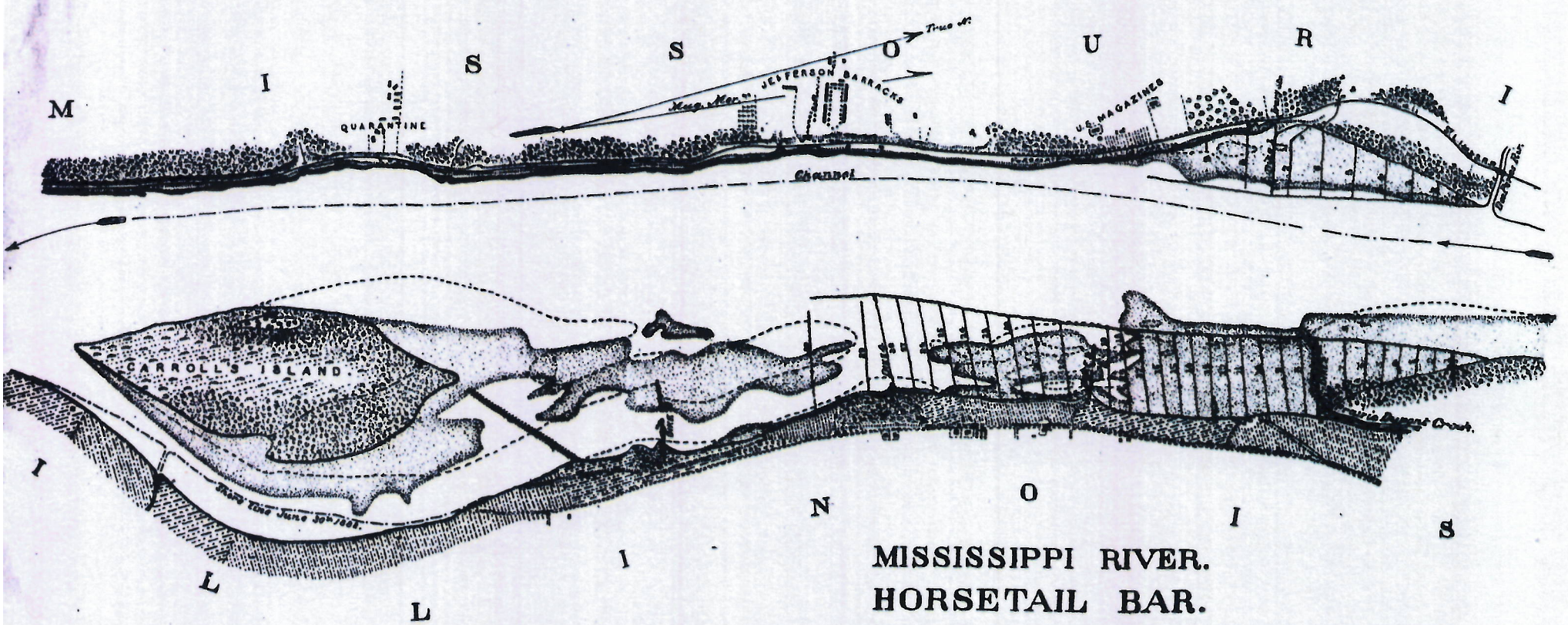
PLATE II.

Improvement of Mississippi between Illinois and Ohio Rivers. Annual Report of Major O. H. ERNST, Corps of Engineers. 1883.



MISSISSIPPI RIVER.
HORSETAIL BAR.

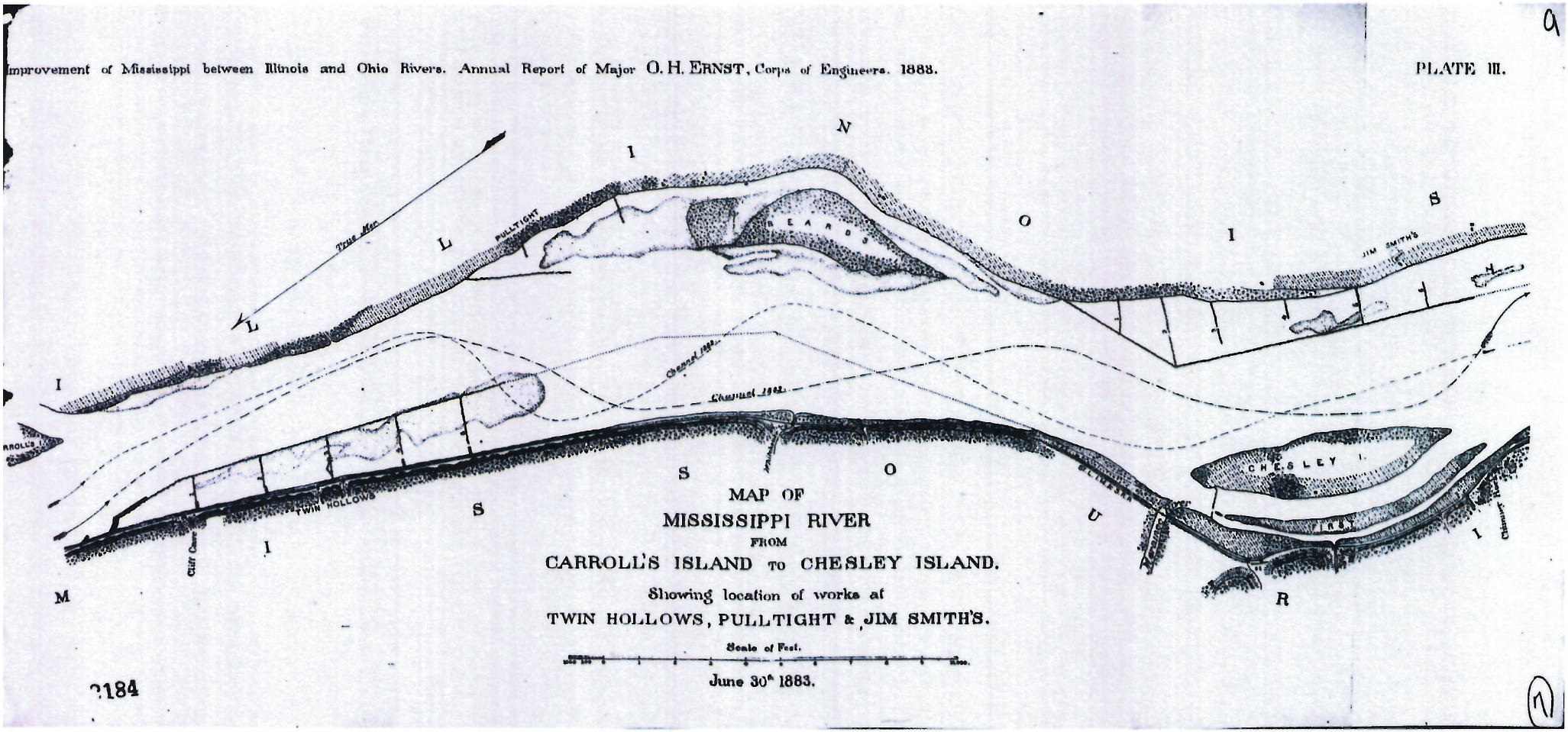
Map showing location of works June 30th 1883.

Bars are shown as they appear at a 11' stage.*

Bars as they appeared at a 11' stage June 30th 1882 represented thus ------

Scale of Feet.

*Standard low water.



MAP OF

MISSISSIPPI RIVER

FROM

CARROLL'S ISLAND TO CHESLEY ISLAND.

Showing location of works at

TWIN HOLLOWS, PULLTIGHT & JIM SMITH'S.

Scale of Feet.

June 30th 1883.

2184

TWIN HOLLOWS, EAST SIDE.
BANK PROTECTION.

Scale of Feet.

Protection placed during year shown thus ▬
previously placed . . ▬

MISSISSIPPI RIVER →

Improvement of Mississippi between Illinois and Ohio Rivers. Annual Report of Major O. H. ERNST, Corps of Engineers. 1883.

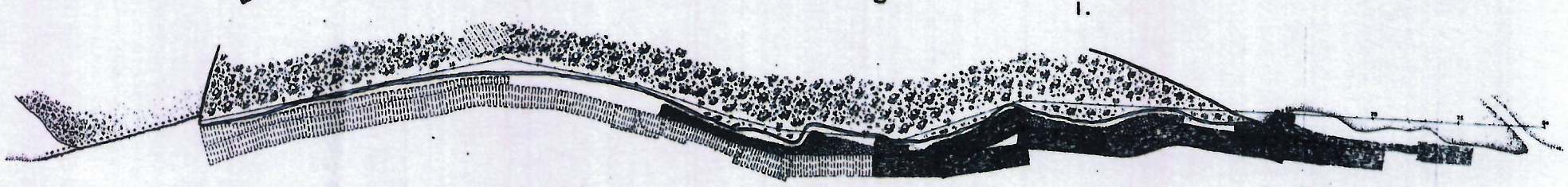
PLATE V.

BEARD'S ISLAND PROTECTION.

Scale of Feet.

Protection placed during year shown thus ▬▬

" previously placed " " ▨▨



M I S S I S S I P P I R I V E R

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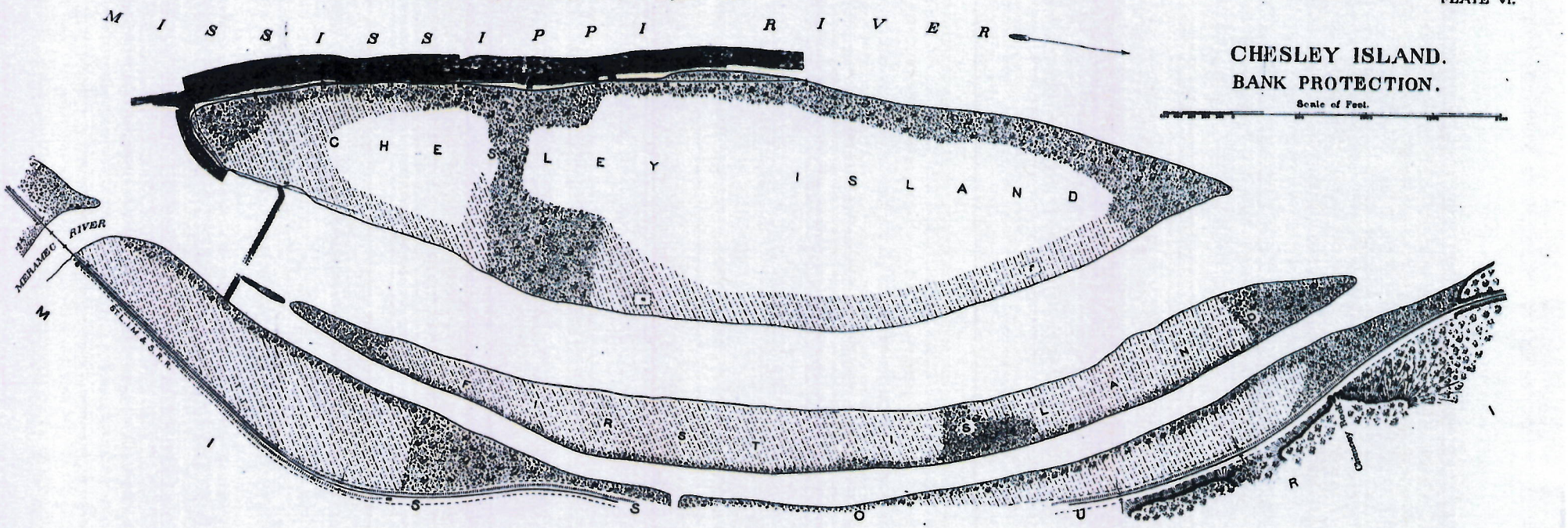
Improvement of Mississippi between Illinois and Ohio Rivers. Annual Report of Major O. H. ERNST, Corps of Engineers. 1888.

PLATE VI.



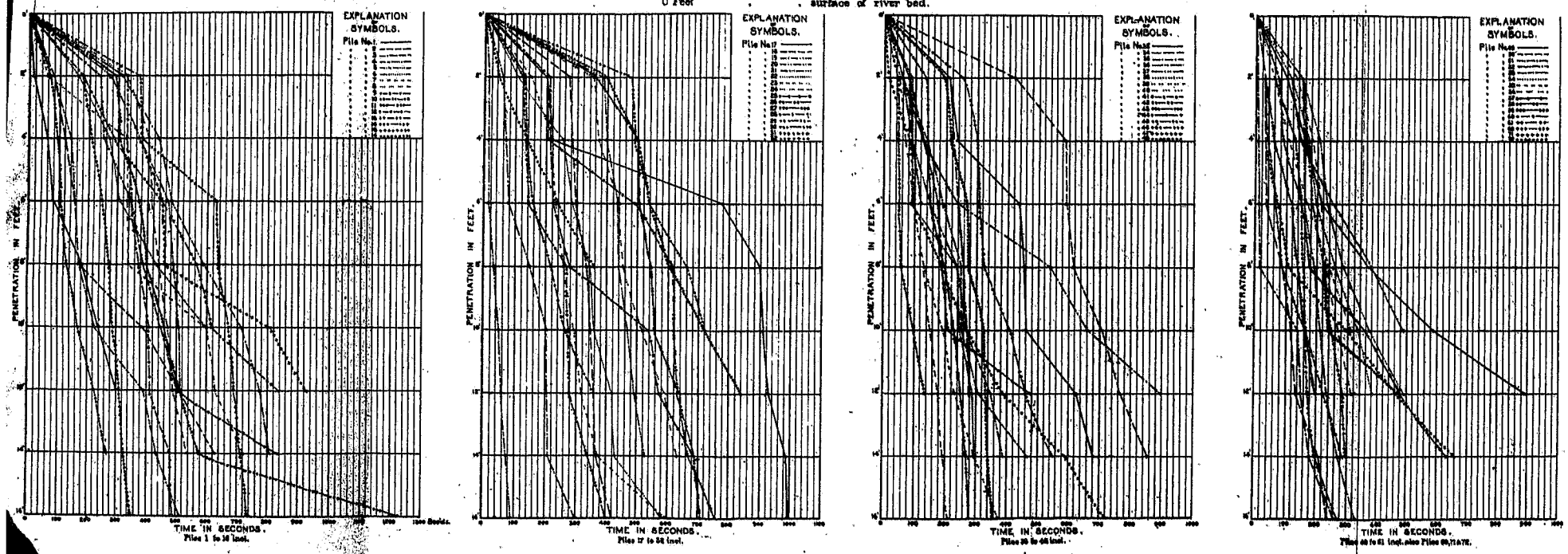
CHESLEY ISLAND.
BANK PROTECTION.

Scale of Feet.

Improvement of Mississippi between Illinois and Ohio Rivers. Annual Report of Major O. H. ERNST, Corps of Engineers. 1888.

PLATE VII.

0 Second corresponds to pile in lands.
0 Feet . . surface of river bed.



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Improvement of Mississippi between Illinois and Ohio Rivers.

Annual Report of Major O. H. ERNST, Corps of Engineers. 1883.

PLATE VIII.

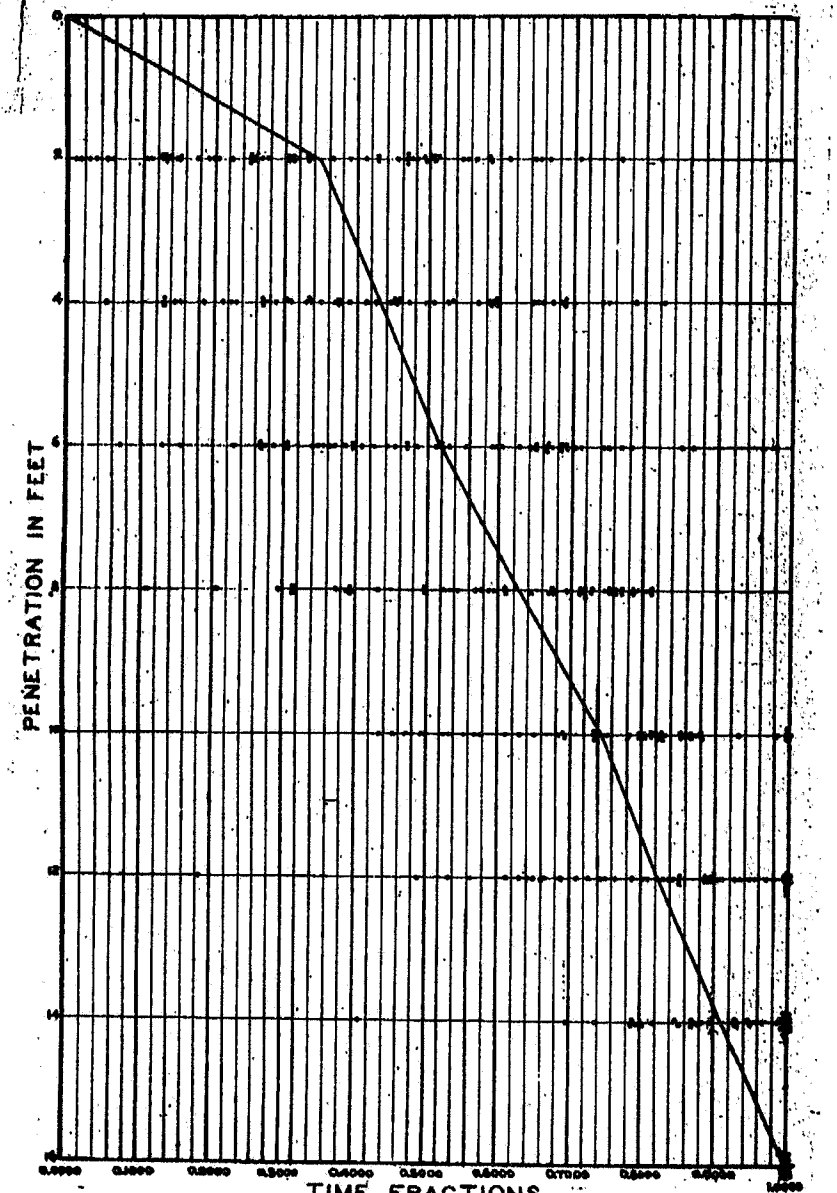

Fig. 1.

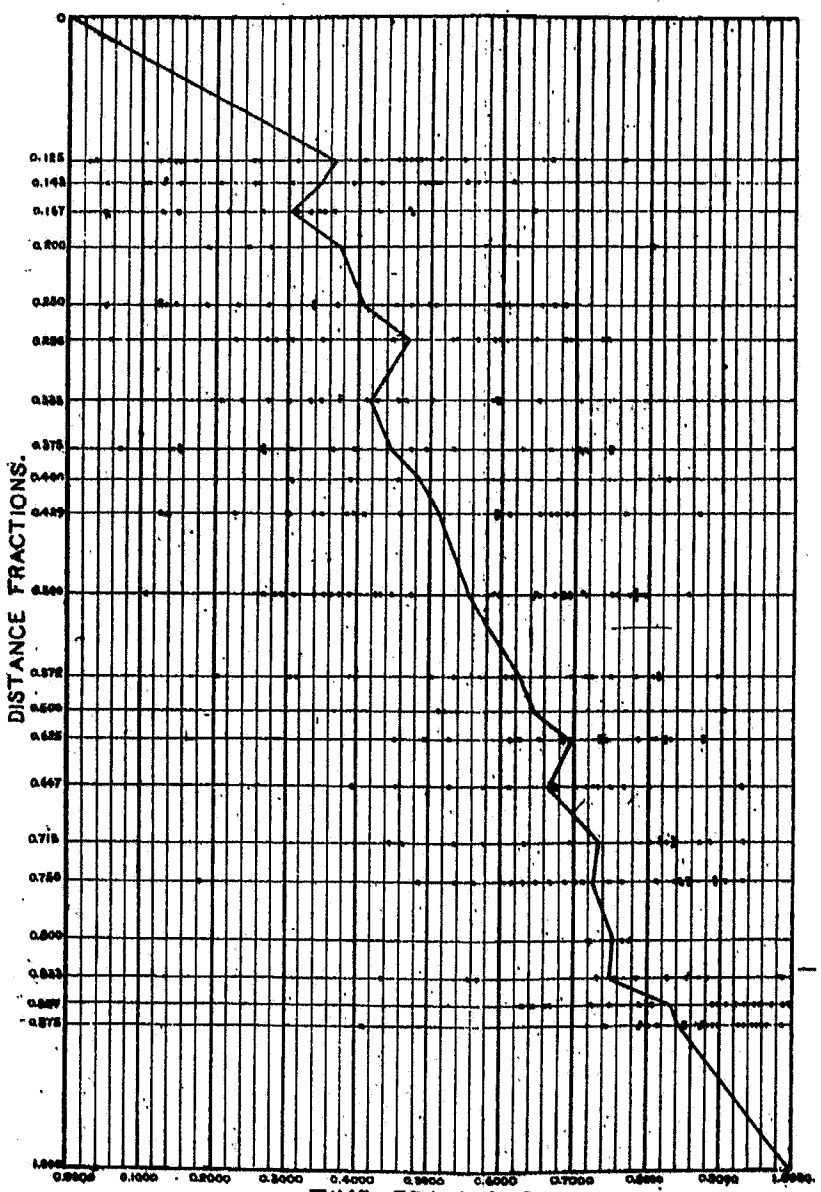

Fig. 2.

2194